Croat Med J 2005;46(5):808-811

B-flow and B-flow Spatio-temporal Image Correlation in Visualizing Fetal Cardiac Blood Flow

Ritsuko K. Pooh, Ayaka Korai

Division of Maternal Fetal Medicine, Center for Maternal, Fetal and Neonatal Medicine, Kagawa National Children's Hospital, Zentsuji, Japan

Aim To evaluate the clinical usefulness of two-dimensional B-flow imaging and four-dimensional (4D) B-flow spatio-temporal image correlation (STIC) as real-time three-dimensional technology in visualizing fetal cardiac blood flow.

Method We examined 65 normal singleton fetuses between 21 and 39 weeks of gestation, using VOLUSON 730 Expert ultrasound device with transabdominal 3D/4D transducer. After visualizing fetal cardiac blood flow by two dimensional B-flow mode, B-flow STIC images were acquired .The acquisition angle was 40° and acquisition time 15 s. The cardiac vascular system was analyzed off-line on multiplanar and reconstructed 3D/4D rendered images.

Results In 38 out of 65 cases, all extracardiac vessels of aortic arch, descending aorta, inferior vena cava, ductus venosus and hepatic vein could be detected on reconstructed 3D/4D images. In all 65 cases, two or more pulmonary veins were easily depicted. On a cardiac back-front view created by rotating 4D reconstructed image, two pulmonary veins among a total of four were depicted in 34 cases (52.3%), three veins in 28 cases (43.1%) and all four pulmonary veins in three cases (4.6%).

Conclusion B-flow and/or B-flow STIC allow visualization of fine small vessels with low velocity, such as pulmonary veins, and may have a great potential for detailed detection of an abnormality of small cardiac vessels, such as total anomalous pulmonary venous return.

A recently developed B-flow imaging technology permits direct gray-scale and non-Doppler visualization of the blood flow in a fetus. The most useful characteristic of B-flow is a better resolution with a higher frame rate on the gray-scale image. The peripheral fine blood vessels can be demonstrated, because of direct visualization of blood reflectors. B-flow is one of the options of gray-scale mode and has no limitation on region of interest (ROI) on two-dimensional (2D) image. Setting of ROI, flow velocity, and pulse repetition frequency, which are usually required in color/power Doppler mode, are not necessary in B-flow, and an easy swift-switching between conventional 2D imaging and B-flow imaging is possible. Furthermore, as B-flow has no angle-dependency, it provides an easier acquisition of image than color Doppler despite the direction or angle of blood vessels.

Spatio-temporal image correlation (STIC) is a four dimensional (4D) ultrasound technology that allows analysis of the image data according to their spatial and temporal domain and processes an online dynamic three-dimensional (3D) image sequence after an automatic volume sweep. Four-dimensional cardiac images are shown on a multiplanar reformatted cross-sectional display and/or a surface-rendered display. By this technology, we

can navigate within the heart, slice in any direction, and produce any standard imaging planes for a comprehensive diagnosis.

Our aim was to evaluate the clinical usefulness of 2D B-flow imaging and 4D B-flow STIC in visualizing fetal cardiac blood flow.

Patients and Method

A total of 65 singleton fetuses between 21 and 39 weeks of gestation without maternal and fetal complications were prospectively evaluated by using STIC and B-flow imaging at our Fetal Ultrasound Unit of Kagawa National Children's Hospital between December of 2004 and February of 2005. No neonatal complications were confirmed after birth on a routine neonatal check and sonographic examination. This study was approved by the local Ethical Committee and informed consent to participate in this study was provided and signed by every mother included in the study.

Ultrasound equipment consisted of VOLUSON 730 Expert (GE Medical Systems Co., Milwaukee, WI, USA) with transabdominal 3D/4D transducer. After demonstrating fetal thoracoabnominal blood flow by 2D B-flow, B-flow STIC images were obtained by a single automatic volume sweep scanning. The angle of acquisition for STIC was 40° and acquisition time 15 s. Obtained volume datasets were saved on the hard disk of the ultrasound equipment. Off-line analyses of blood vessels were done on three orthogonal images, which can provide multiplanar tomographic images in any plane, and spatial reconstructed volume-rendering images, which show the superficial blood vessels.

Results

Two dimensional B-flow images and three dimensional B-flow by automatic scanning were easily obtained in all 65 cases without any artifacts caused by maternal or fetal motion. In all 65 cases, extracardiac vessels – the aortic arch, descending aorta, inferior vena cava, ductus venosus and hepatic vein – were detectable on the three orthogonal views of multiplanar imaging and reconstructed image of fetal thoracoabdominal vascular system by B-flow STIC (Fig. 1). On the reconstructed B-flow STIC, volume rendering image was rotated and each extracardiac vessel was confirmed from different directions (Fig. 2). Practically, those images were demonstrated not only as

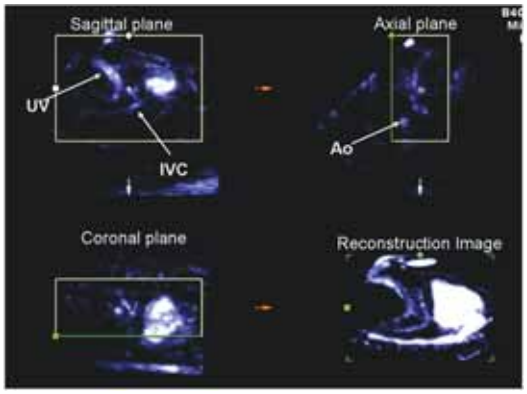

Figure 1. B-flow STIC image at 26 weeks of gestation. Three orthogonal views and reconstructed image of fetal thoracoabdominal part by B-flow STIC, which could also be visualized as 4D cine images with cardiac motion. UV – umbilical vein, IVC – inferior vena cava, Ao – aorta.

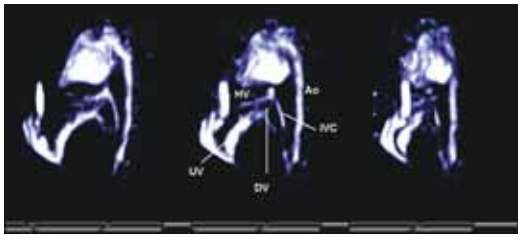

Figure 2. B-flow STIC volume rendering image from three directions at 26 weeks of gestation. Rotated pictures of the ductus venosus (DV), inferior vena cava (IVC), descending aorta (Ao), umbilical vein (UV) and hepatic veins (HV).

static images but also as 4D cine images with cardiac motion. However, all those vessels were clearly shown on a single 4D reconstructed image in 38 out of 65 cases and in the remaining 27 cases, one or more extracardiac vessels were blurred because of artifacts, so they could not be clearly identified on the reconstructed 4D image.

In all 65 cases, two or more pulmonary veins from the lung toward the left atrium could be easily depicted by both 2D B-flow mode and B-flow STIC reconstructed imaging. 2D coronal cutting section of B-flow image among the multiplanar views and 3D thick slice image of two pulmonary veins from the right and left lung into the left atrium could be visualized (Fig. 3). By rotation of the 4D B-flow STIC cardiac superficial view to visualize the pulmonary veins towards the left atrium on a back-front view of the heart, two pulmonary veins among a total of four veins were depicted in 34 cases (52.3%), three veins in 28 cases (43.1%), and all of four pulmonary veins from the

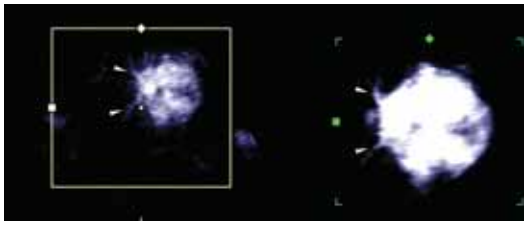

Figure 3. B-flow image of bilateral pulmonary veins at 27 weeks of gestation. A coronal cutting plane is shown from three orthogonal views (left) and 3D thick-slice image of bilateral pulmonary veins (arrowheads).

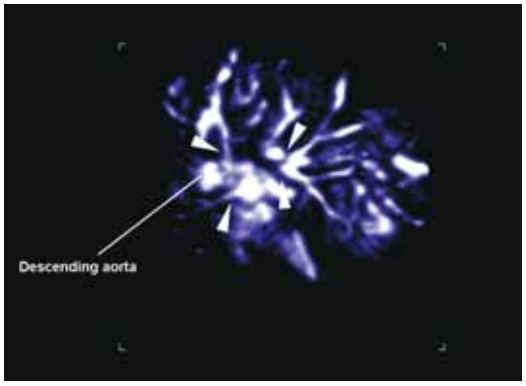

Figure 4. Backside view of the cardiac B-flow STIC image at 33 weeks of gestation. Four pulmonary veins (arrowheads) from the bilateral lung toward the left atrium were detectable by rotating reconstruction image and demonstrated as a 4D cine image with cardiac motion.

bilateral lungs toward the left atrium could be successfully demonstrated on a single reconstructed view in three (4.6%) cases (Fig. 4) at 30, 33, and 35 weeks of gestation, respectively.

Discussion

B-flow is a unique technology that uses digitally encoding techniques to suppress tissue clutter and improves sensitivity for the direct visualization of blood reflectors. In general, non Doppler B-flow sonoangiography has many advantages in comparison with color Doppler imaging, such as significantly lower angle dependency, lower interference with frame rate, no need to set ROI, no interference with gain or flow velocity, better resolution and better visualization of hemodynamics. There have been several reports of B-flow used for detection of stenotic lesion in the cervical carotid artery (1-3) and the evaluation of liver blood vessels and intratumoral vessels (4,5). Yurdakul et al (3) reported that B-flow imaging showed high correlation with digital subtraction angiography and provided more accurate planimetric evaluation of the internal carotid artery stenosis than did power Doppler. An application of B-flow in perinatology was first reported by Pooh (6) in 2000, showing that B-flow imaging could realistically demonstrate the small peripheral vessels, such as the lenticulostriate arteries of neonatal brain. B-flow shows only moving blood particles inside the blood vessels, whereas color/power Doppler signals, which are larger than B-mode pixels, are superimposed onto the B-mode structural layer and blood flow is demonstrated as exaggerated and blurred vascular image. Therefore, vascular flow in the blood vessels is more realistically represented and more clearly delineated on B-flow than on color/power Doppler image.

STIC (7-9) 4D ultrasound is a new approach in clinical assessment of the fetal heart. STIC is an easy-to-use technique to acquire data on the fetal heart that allows visualization with both 3D static images and 4D sequences. DeVore et al (7) reported the many advantages of STIC in evaluation of the fetal heart, such as a temporal resolution with a high frame rate, an unlimited number of images, and a looped cine sequence imaging for review. It allows for correlation between image planes perpendicular to the main image acquisition plane, shortening of the evaluation time, obtaining the reconstruction of a 3D rendered image with additional information that is not available from the thin multiplanar image slices, and reviewing volume data at a remote site. Combination of STIC technology with color/power Doppler technique was introduced in 2003. Chaui et al (10) evaluated normal and abnormal fetal hearts by color Doppler STIC, suggesting it as a promising new tool for multiplanar and 3D/4D rendering of the fetal heart despite limitations in fetuses of late gestation with large hearts because of angle limitation of STIC and fetuses of early gestation with low discrimination of color signals because of low blood flow velocity in small fetuses. Unlike color/power Doppler, B-flow can demonstrate fine peripheral vessels with low flow velocity. This is the reason why B-flow may be potentially used as an imaging technique in fetal cardiac imaging (11) and may compensate for limitations of color/power Doppler technology. B-flow technology was combined with STIC in 2004 and Goncalves et al

(12) were the first to report on the use of B-flow STIC imaging. They showed that images created by B-flow STIC and inversion mode as 'digital casts' and this modality allowed visualization of the relationships, size, and course of the outflow tracts, thus helping the examiner to better understand the spatial relationships between the vessels.

We used B-flow for visualization of fetal cardiac blood vessels and found that not only extracardiac vessels, such as aorta, ductus venosus, inferior vena cava, and hepatic veins, but also small vessels with low velocity blood flow such as pulmonary veins could be immediately identified on 2D B-flow and examined in detail on saved image data of B-flow STIC. In fetuses that we examined, two or more pulmonary veins were detectable in all cases. Because the pulmonary veins were located in the backside of the heart and it was difficult to demonstrate all four pulmonary veins by conventional ultrasound techniques of B-mode, color/power Doppler and even by 2D B-flow. Moreover, showing four pulmonary veins on a single image has been impossible by any ultrasound technology. Even with B-flow STIC, successful acquisition of all four pulmonary veins is difficult because of their location, smallness and low-velocity. However, we managed to visualize all four pulmonary veins clearly in only three cases. To the best of our knowledge, this is the first report on clear demonstration of four pulmonary veins in a single 4D view. We believe that B-flow STIC may have a great potential for detailed detection of a small cardiac vascular abnormality, such as total anomalous pulmonary venous return.

The limitation of B-flow STIC is that it provides no information on blood flow direction. Visualization of the extracardiac great vessels is possible by B-flow STIC, however, intracardiac vascular flow is not clearly detected because of lack of information of blood flow direction. Combination of both color Doppler STIC with directional information and B-flow STIC with identification of fine vascular flow may be useful for obtaining cardiac vascular information.

In conclusion, B-flow and/or B-flow STIC can contribute to detailed information of cardiac vascular blood flow in fetal echocardiography, because it provides easy and objective identification of small vessels. This unique technology may be a promising tool in detecting fine blood vessels, such as fetal/neonatal renal and brain vessels and placental blood flow in a field of perinatology.

References

1 Umemura A, Yamada K. B-mode flow imaging of the carotid artery. Stroke. 2001;32:2055-7.

2 Tola M, Yurdakul M, Cumhur T. Combined use of color duplex ultrasonography and B-flow imaging for evaluation of patients with carotid artery stenosis. AJNR Am J Neuroradiol. 2004;25:1856-60.

3 Yurdakul M, Tola M, Cumhur T. B-flow imaging of internal carotid artery stenosis: comparison with power Doppler imaging and digital subtraction angiography. J Clin Ultrasound. 2004;32:243-8.

4 Furuse J, Maru Y, Mera K, Sumi H, Yoshino M, Yokoyama Y, et al. Visualization of blood flow in hepatic vessels and hepatocellular carcinoma using B-flow sonography. J Clin Ultrasound. 2001;29:1-6.

5 Ono N, Ijuin H, Suga H, Okabe Y, Yakushiji K, Hashiguchi M, et al. B-Flow contrast US with Levovist in hepatic tumors: preliminary results. Kurume Med J. 2003;50:21-5.

6 Pooh RK. New application of B-flow sono-angiography in perinatology. Ultrasound Obstet Gynecol. 2000;15: 163.

7 DeVore GR, Falkensammer P, Sklansky MS, Platt LD. Spatio-temporal image correlation (STIC): new technology for evaluation of the fetal heart. Ultrasound Obstet Gynecol. 2003;22:380-7.

8 Vinals F, Poblete P, Giuliano A. Spatio-temporal image correlation (STIC): a new tool for the prenatal screening of congenital heart defects. Ultrasound Obstet Gynecol. 2003;22:388-94.

9 Goncalves LF, Lee W, Chaiworapongsa T, Espinoza J, Schoen ML, Falkensammer P, et al. Four-dimensional ultrasonography of the fetal heart with spatiotemporal image correlation. Am J Obstet Gynecol. 2003;189: 1792-802.

10 Chaoui R, Hoffmann J, Heling KS. Three-dimensional (3D) and 4D color Doppler fetal echocardiography using spatio-temporal image correlation (STIC). Ultrasound Obstet Gynecol. 2004;23:535-45.

11 Deng J, Rodeck CH. New fetal cardiac imaging techniques. Prenat Diagn. 2004;24:1092-103.

12 Goncalves LF, Espinoza J, Lee W, Nien JK, Hong JS, Santolaya-Forgas J, Mazor M, Romero R. A new approach to fetal echocardiography: digital casts of the fetal cardiac chambers and great vessels for detection of congenital heart disease. J Ultrasound Med. 2005;24: 415-24.

Received: April 26, 2005
Accepted: August 15, 2005

Correspondence to:
Ritsuko K. Pooh
Division of Maternal Fetal Medicine
Center for Maternal, Fetal and Neonatal Medicine
Kagawa National Children's Hospital
Zentsuji 2603, Zentsuji City
Kagawa #765-8501, Japan
rkpooh@guitar.ocn.ne.jp