GE Healthcare

Application of transabdominal STIC color in the first trimester

A. NOCUN

Medical Practice
IPL Agnieszka Nocun,
Krakow, Poland

M. WIECHEC

Centre for Fetal Care,
Imperial College Healthcare,
London, UK

INTRODUCTION

Spatial and Temporal Image Correlation (STIC) has become a widely accepted technique in 2nd and 3rd trimester fetal echocardiography since its introduction in 2003. Performing a STIC acquisition of a fetal heart involves acquiring one slow 3D sweep of approximately 10 seconds duration across the fetal thorax. During this sweep the fetal heart beats approximately 20-28 times. The machine detects the location and timing of each systolic beat and calculates the heart rate. Then the system determines the time frame between each beat which allows rearranging of the B-mode frames into a new order depending on their temporal event within the heart cycle. Since the machine knows the length of the sweep and the heart rate it can calculate the location of each peak systolic frame and other points in the cardiac cycle and combine the information in it with all the other frames of the corresponding times. Because many frames at the exact time reference are averaged together the temporal resolution compares to a high frame rate B-mode image. The rearranging results in a final product of one heart cycle replayed in a continuous cine loop. Since each frame represents a volume of information, the image can be reconstructed in different planes for the examination of fetal cardiac structures from many angles[1].

The benefits of this technique with the addition of color Doppler were initially described in 2004[2,3]. For utilization with early 2D fetal echocardiography the addition of color Doppler is necessary in order to exclude such conditions as valvular lesions and septal defects[4].

When a small structure, such as the fetal heart in the first trimester, needs to be captured into a volume, the angle of acquisition needs to be set according to the size of the object. We describe this technique as targeted acquisition. When the volume sweep angle is larger than the structure being examined it causes redundant information to be included in the volume and the volume itself to be of reduced resolution. Using a targeted acquisition technique, the smaller the object the faster the time of acquisition. When the time of acquisition is short then the chance of the occurrence of motion artifacts is minimal. This is extremely important in an active first trimester fetus. In the following white paper we describe a technique of targeted volume acquisition which results in high quality STIC color imaging.

Obtaining high quality first trimester STIC volumes requires a high level of practical and theoretical education in early fetal echocardiography together with 2nd and 3rd trimester STIC acquisitions. Also, ultrasound systems must be equipped with state of the art processing and appropriate transducers to produce the images. On GE Voluson systems, the 4-8MHz volume transducer is capable of producing high quality 2D, color fetal heart and STIC images[5]. Because satisfactory 2D imaging is not always a guarantee of good volume imaging, it is also extremely important to be familiar with modern image enhancers and filters which reduce speckle artifacts so as to not risk rewriting them into the volume dataset.

PRE VOLUME ACQUISITION 2D AND COLOR SETTINGS

2D SETTINGS

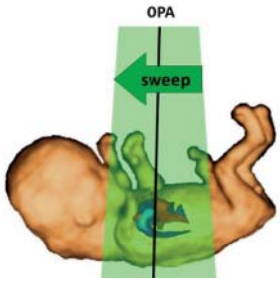
It is important to begin the STIC process by setting optimal 2D and color parameters. Using the 4-8 MHz GE Voluson volume transducer, begin by choosing the "first trimester cardiac" application setting. Also utilize - high harmonics, a high SRI (4-5) and a low CRI (1-2). Optimize the 2D dynamic range control (6-9) and the rejection control for the particular patient. Because in the first trimester the fetal heart is so small (6 mm- 10 mm across), it is crucial to utilize the maximum available high resolution zoom box which creates a field of approximately 24 mm x 29 mm in the axial view. This allows for the highest spatial and temporal resolution possible.

COLOR SETTINGS

The next step is the application of color Doppler. Because the addition of color rapidly reduces the frame rate, try to maintain the highest rate possible by reducing the color quality (mid or low) and color frequency (mid or low) levels. Other color settings that need optimization are; PRF (2.4KHz), gain (negative 4.2 – 7.8), wall motion filter (mid-2), line density (6-8), line filter (3-7), smooth rise filter (2) smooth fall filter (3), ensemble (10) and balance (100).

STIC VOLUME ACQUISITION SETTINGS

STIC techniques were designed for 2nd trimester imaging. The smallest available volume acquisition angle is 15 degrees. The schematic diagram below demonstrates the second trimester technique of finding the geometric center of the heart with 2D. That slice becomes what is termed the original plane of acquisition (OPA). The volume is created by then mechanically sweeping the beam 7.5 degrees from the OPA. The volume acquisition then begins, coming back towards the OPA and then continuing for another 7.5 degrees to create a 15 degrees volume of information.



The following volume ultrasound images demonstrate how much redundant information is obtained when using a 15 degree angle on a 1st trimester heart.

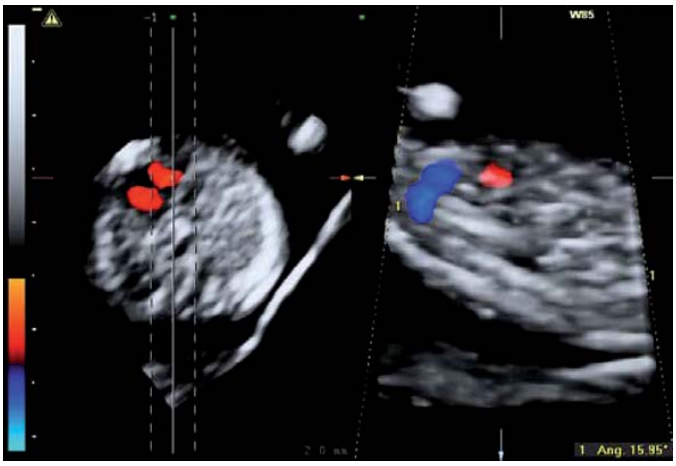


Figure 1. Tomographic ultrasound image (TUI) of a 12 week 3 day fetal heart using 2nd trimester technique of a 15 degree angle. On the left is the A plane which was the acquisition plane in an axial view. On the right is the reconstructed B plane seen in a sagittal view, 90 degrees from the A plane. The pictures clearly show how small the fetal heart is in relation to the size of the whole volume. Notice how much unnecessary captured data is seen around the fetal heart especially in the B plane.

In order to start the sweep the acquisition angle and time may be chosen by the operator. The available sweep angle range is between 15 and 40 degrees and the time range is between 7.5 and 15 seconds. The longer the sweep time, the more frames collected during the volume and the better the spatial resolution. However, it is desirable to shorten the acquisition time in order to avoid motion artifacts caused by a moving fetus.

HIGH QUALITY FIRST TRIMESTER STIC COLOR TECHNIQUE (HQ 1ST TRIMESTER STIC)

Appling the second trimester conventional technique in the first trimester always results in volumes in which the fetal heart is very small in comparison to the whole volume and the image quality is suboptimal compared to what is considered good quality in the second trimester.

To optimize the technique for the first trimester there are 2 changes that are made to the second trimester protocol. Operator is facing the patient sitting on her right side. A 20 degree sweep angle and a 12.5 second sweep are chosen. Then the center of the heart (the OPA) is identified at a point where the inflow to the ventricles is seen as 2 color stripes (see Figure 4), which is the initial acquisition view. To obtain this initial view, when the fetus is in a transverse lie, the transducer is rotated counterclockwise. No rotation is needed in longitudinal fetal lie. The OPA is then shifted away from the center of the heart and placed at either the inferior or superior border of the heart, depending on fetal position (see figures 2 and 3). The FREEZE button is then pushed to begin the acquisition. The machine then begins the sweep away from the OPA and moves back towards the OPA. When the sweep reaches its halfway point, which coincides with the location of the modified OPA, you must then hit the button which stops the acquisition. This is EXIT-Stop acquisition on the touch screen for the Voluson E8 or the 730 Expert, and the EXIT button on the keyboard for the Voluson 730 Pro model. This manually stops the acquisition just after it reaches its midpoint of approximately 11 degrees and allows for the use of the high quality settings (12. 5 sec sweep) however only approximately 7 seconds of the sweep are used. Because only half of the 12.5 second sweep time is used this minimizes the risk of artifacts due to fetal movement.

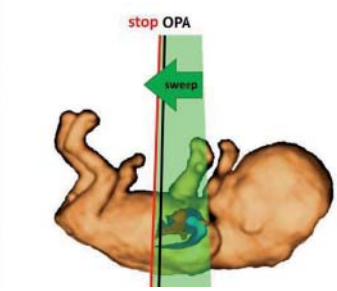


Figure 2. HQ 1st trimester STIC technique. This figure shows the OPA placement at the level of ductus venosus which is used when the fetus is in the cephalic or a transverse left position. The sweep starts from just above the fetal heart and is broken manually after it reaches the starting point which is the OPA. This technique utilizes an approximately 11 degree angle and an approximately 7 sec sweep time.

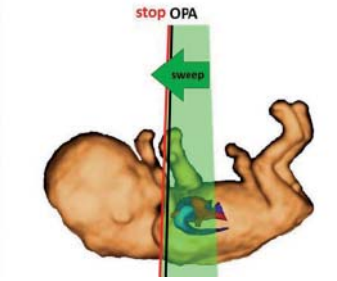


Figure 3. HQ 1st trimester STIC technique. The figure shows the OPA placement at the level of the mandible which is used when the fetus is in the breech or transverse right position. The sweep starts from just below the fetal heart and is broken manually after it reaches the starting point which is the OPA. This technique utilizes an approximately 11 degree angle and an approximately 7 sec sweep time.

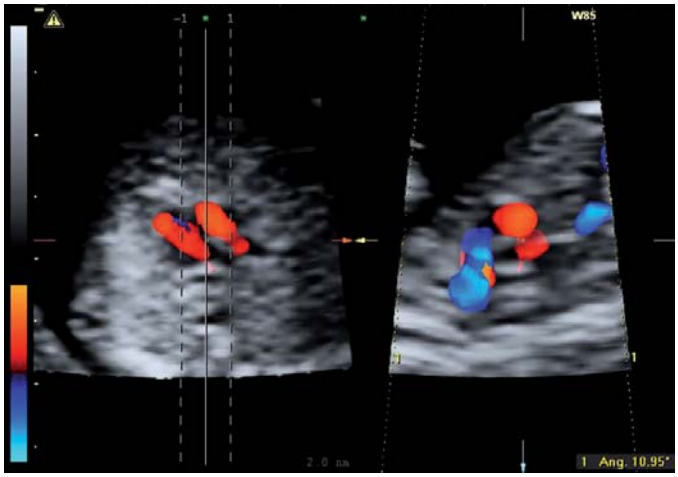


Figure 4. Result of a volume acquisition using HQ 1st trimester STIC technique. The fetal heart occupies a large portion of the volume. An acquisition angle of approximately 11 degrees and 7 second sweep time was successfully utilized maximizing image resolution[6].

OPTIMAL POSITION OF THE FETUS FOR HQ STIC

The success of the HQ STIC first trimester technique is highly dependent on the use of color. The same limitations for the use of color in 2D apply to volume imaging, particularly the angle of incidence of the beam. The 2 most important views in first trimester STIC are two color stripes corresponding with the ventricular inflow the at the level of 4 chamber view and the V sign in color due to the confluence of the ductus arteriosus and the aortic isthmus at the level of three vessel and trachea view[6]. To see these views in color it is imperative that the fetal heart be in a good position. The optimal position of the fetus for 1st trimester color STIC is when the angle between the beam and the intraventricular septum is 40±5 degrees in axial plane. In this position the interventricular septum and the crux are also optimally seen in 2D.

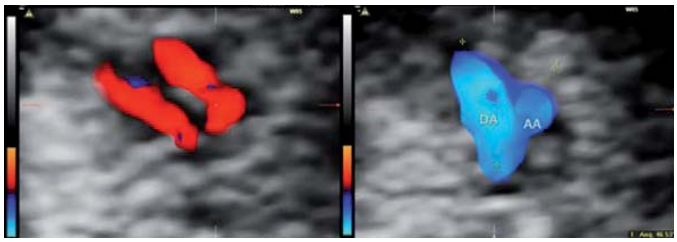


Figure 5. A 12 week + 3 day fetal heart showing images of the inflow view of the ventricles (left) and the V sign (right) with the optimal angle between the beam and intraventricular septum.

STIC VOLUME REVIEW

Just after acquiring the acquisition, it is recommended that you quickly review the volume before saving it. The proposed way is to do this is to move the reference dot horizontally at the level of the heart in the B plane and assess volume quality in the A and C planes[6].

For post acquisition volume review, there are 3 available viewing options. The multiplanar view, Tomographic Ultrasound Imaging (TUI) or rendering, can be used. In the A plane, these views can be assessed: an axial view of the abdomen (abdominal situs), the ventricular inflow at the level of 4 chamber view, an aortic outflow in color at the level of five chamber view, a right outflow tract view in color and also the V-sign[7,8,9,10] (figure 6). Because the HQ 1st Trimester color STIC technique creates images with high quality spatial and temporal resolution, the B and C planes are also of excellent quality. In the B plane the ductal and aortic arch views in color are well seen (figure 7). In the C plane the coronal 'en-face' view at the level of the atrio-ventricular valves (figure 8) and the level of the semilunar valves[11] (figure 9) help to assess arrangement of the valves.

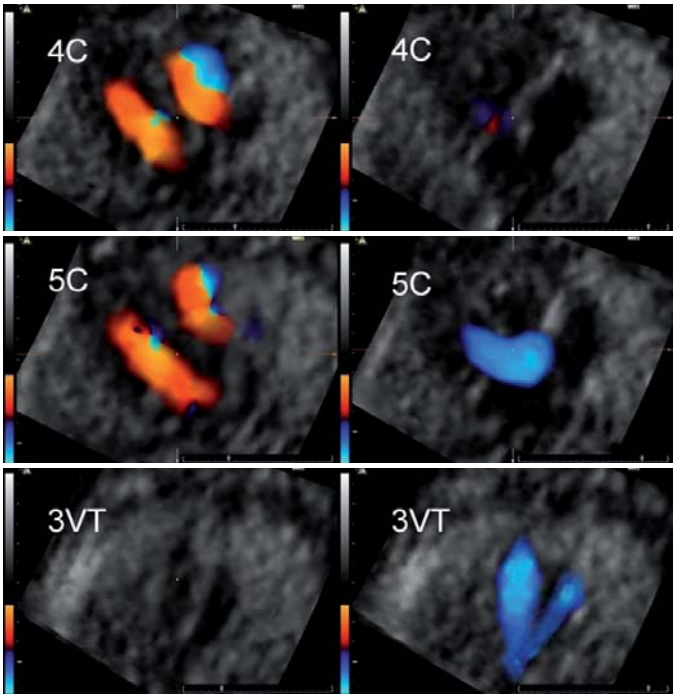


Figure 6. Frames showing basic cardiac views taken during volume review. The left column represents diastole and the right column systole (13 weeks and 6 days).

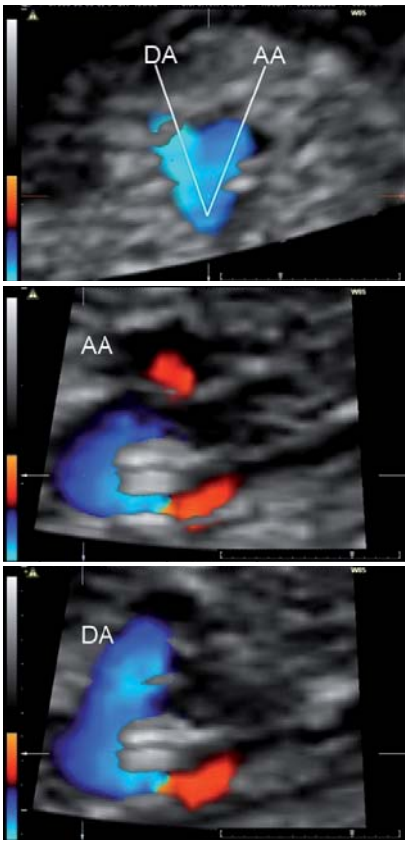


Figure 7. Top) A plane V sign. Middle) B-plane aortic arch. Bottom) B-plane ductal arch (13 weeks and 3 days).

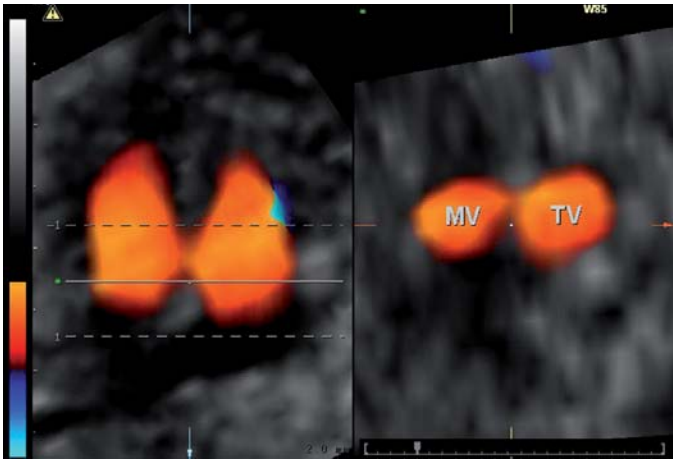


Figure 8. Split screen TUI display. Left) the 4-chamber view of the ventricles in diastole. Right) "en-face" coronal view of the inflows in diastole (13 weeks and 5 days).

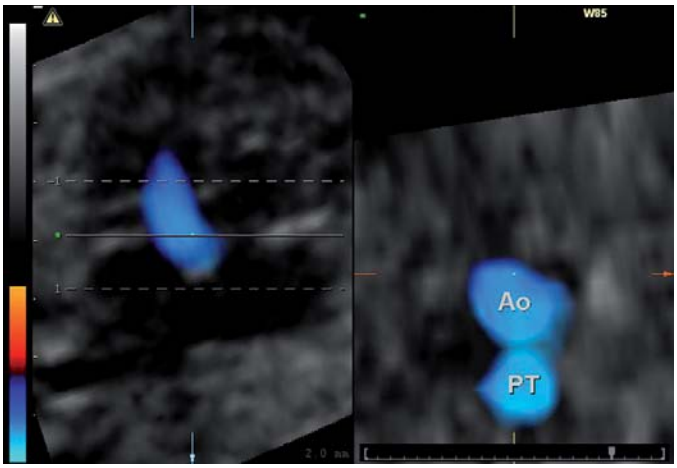


Figure 9. Split screen TUI display. Left) 4-chamber view of the aortic outflow. Right) "en-face" coronal view of the semilunar outflows in systole (13 weeks and 5 days).

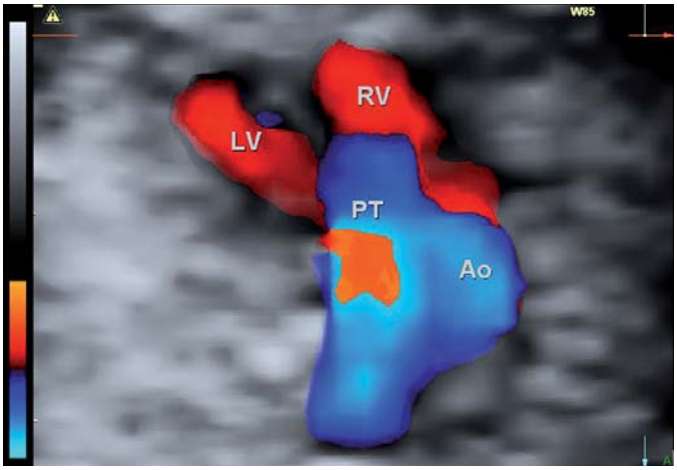


Figure 10. Glass body rendering of a 12 week + 3day fetal heart in a STIC color volume.

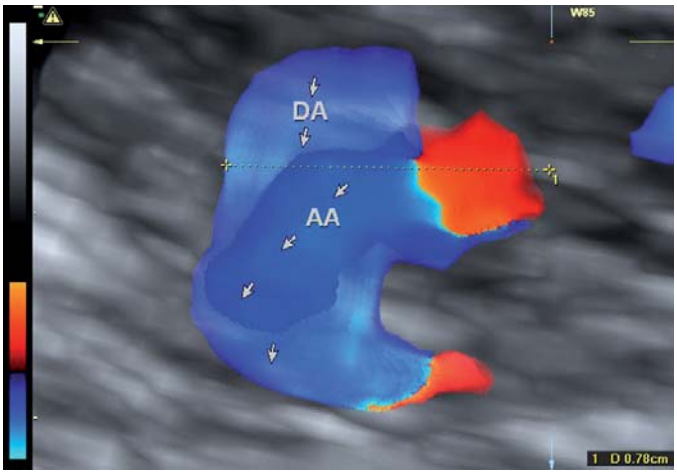


Figure 11. Glass body rendering of of a 12 week + 3day fetal heart showing the ductal and aortic arches in a STIC color volume.

CONCLUSION

Spatial and Temporal image correlation merges the benefits of volume imaging with the application of fetal echocardiography.

The benefits of 2nd trimester STIC can now be moved into the first trimester with high quality results to allow earlier suspicion of congenital heart disease. Post acquisition volume review in multiple viewing planes can assess spatial relationships between cardiac structures in orthogonal planes. In a single block of datasets all of the basic cardiac views can be evaluated along with additional views in motion. In authors opinion STIC broadens the application of early fetal echocardiography in the first trimester.

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