BSI
(Blood Speckle Imaging)

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Introduction

Ultrasound Doppler imaging is essential in the evaluation of intracardiac blood flow. Visualization of flow disturbances is important for understanding hemodynamics in children with congenital heart disease and for diagnosis and therapeutic planning in children with acquired and congenital heart disease.

Blood flow imaging using conventional color Doppler technology is limited due to Doppler angle dependency (display of only radial velocities) and aliasing (velocity scale is limited by the pulse repetition frequency ("Nyquist limit"). Blood Speckle Imaging (BSI) is a novel blood flow visualization technique partially overcoming both limitations in conventional color flow imaging.

Method

BSI is based on tracking of speckles generated by the moving blood cells from one frame to the next using a “best match” search algorithm. This allows direct assessment of two-dimensional blood velocity vectors without requiring injection of contrast agent and without the mathematical assumptions of approaches based on conventional color Doppler. Due to the high rate of decorrelation of moving blood speckles, the acquisition frame rate must be much higher than that used in myocardial speckle tracking, Automated Function Imaging (AFI) or 2D Strain. Typical acquisition framerates for BSI are in thousands of frames per seconds (FPS) range, but is reduced to 400-600 FPS on display (depending on the size of the Region of Interest (ROI)). To review the loops after acquisition, they are displayed in slow motion.

This ultrahigh framerate acquisition is obtained using a plane wave imaging technique. This method is based on utilizing broad transmit beams allowing multi-line acquisition of a much higher degree than used previously. In plane wave imaging, an unfocused wave propagates in a floodlight fashion, with a wide beam at both shallow and deep depths. See Figure 1.

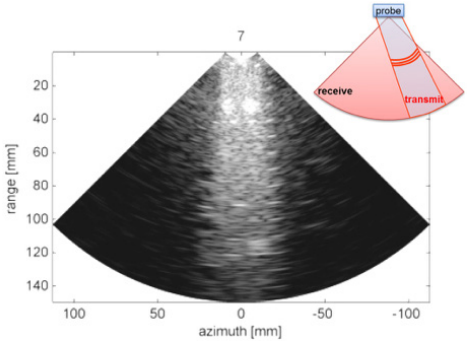

Figure 1. Plane wave imaging, schematic illustration and tissue phantom recording.

Limitations of plane wave transmit technology are the reduction of penetration and signal to noise ratio, and the technique is currently only available in fundamental imaging using higher frequency probes at relative shallow depths (typically less than 10-12cm).

BSI workflow description

BSI is available in the Neonatal and Pediatric presets for the 6S-D and 12S-D probes, and in the Cardiac presets for the 6VT-D probe. While in conventional color flow, pressing the Blood Speckle Imaging button on the scanner touch panel activates the **BSI acquisition mode**. In this mode, data from the blood speckle is acquired at very high framerates and displayed together with color-Doppler information, while the underlying 2D images are acquired at a normal framerate. See Figure 2. As can be seen, the BSI image is somewhat grainy in appearance, and some vertical stripes may be observed due to the different broad beam image acquisition.

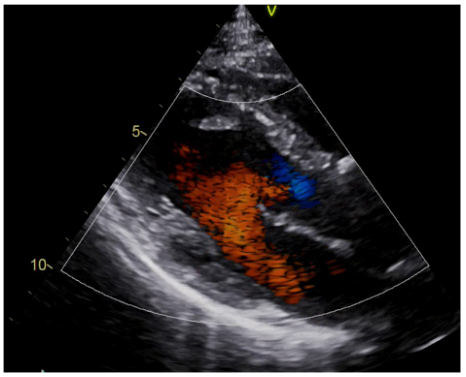

Figure 2. BSI appearance, blood speckle is shown superimposed over color-Doppler images

Currently, blood flow tracking is not available during live scanning due to the high number of blood speckles that must be tracked at very high framerates. Visualization can only be done either when recalling a stored BSI loop, or in the “Preview loop before store” mode. In both display modes, the user has to press the **Show Particles** button on the touch panel to initiate the tracking calculation and display of the blood flow trajectories.

A few controls are available for the user to optimize the display as well as the replay speed of the loop, which usually is played in slow motion to clearly see the dynamics of the blood flow. Conventional red/blue color mapping together with a blood particle visualization are added to further enhance visualization and understanding of the flow patterns. See Figure 3.

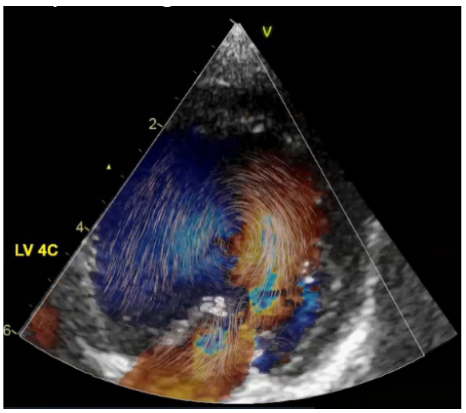

Figure 3. BSI particle visualization portraying the vortex formation in a child with a dilated left ventricle.

Validation

The velocities of the tracked blood speckle have been validated in vitro using flow rigs and rotating tissue-mimicking phantoms. A cylinder of tissue-mimicking material was made using an agar solution and coupled to a stepper motor. A uniform rotation was setup, providing a theoretical ground truth as reference for the measurements. In Figure 4, arrows indicate the measured velocities based on blood speckle imaging for a rotating tissue-mimicking phantom, demonstrating that blood can be measured in a more angle-independent manner.

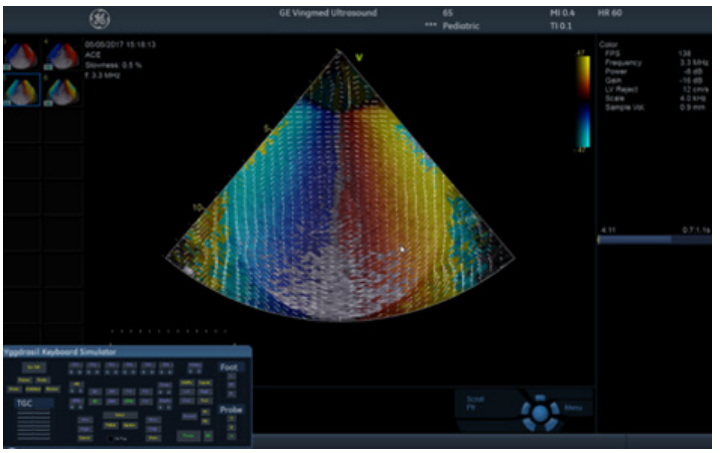

Figure 4. Validation of BSI using a rotating cylinder of tissue-mimicking material.

Imagination at work

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