High frame rate synthetic aperture duplex imaging

Conventional color flow images are limited in velocity range and can either show the high velocities in systole or be optimized for the lower diastolic velocities. The full dynamics of the flow is, thus, hard to visualize. The dynamic range can be significantly increased by employing synthetic aperture flow imaging as demonstrated in this paper. Synthetic aperture, directional beamforming, and cross-correlation are used to produce B-mode and vector velocity images at high frame rates. The frame rate equals the effective pulse repetition frequency of each imaging mode. Emissions for making the B-mode images and velocity maps are interleaved in a 1-to-1 ratio. This provides continuous data allowing a wide range of velocities to be estimated. Two cases are considered in the flow estimation: In the first case, the angle of the flow is determined from the B-mode image. In the other case, the angle is determined by estimating the flow velocity in all directions and choosing the one with the strongest correlation. The method works for all angles, including fully axial and fully transverse flows. Field II simulations with a 192 element, 7 MHz linear array are made of laminar, transverse flow profiles. For a simulated peak velocity of 0.5 m/s, the relative bias is −6.8% and the relative standard deviation is 6.1%. The bias on the angle is 0.98 degrees with a standard deviation of 2.39 degrees when using the flow estimator to determine the angle. For a peak velocity of 0.05 m/s, the relative bias of the velocity estimation is −1.8% and the relative standard deviation 5.4%. The approach can thus estimate both high and low velocities with equal accuracy and thereby makes it possible to present vector flow images with a high dynamic range. Measurements are made using the SARUS research scanner, a linear array transducer similar to the simulated one, and a recirculating flow rig with a blood mimicking fluid and a parabolic flow profile with a peak velocity of approximately 0.3 m/s. The relative bias of the velocity estimation is 0.19% and the mean relative standard deviation 4.9%. For the direction estimation, the bias is 3.2 degrees with a standard deviation of 1.6 degrees.