Accurate, highly time resolved flow rate and volume quantification with multiview 3D Colour Doppler echo

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Introduction:
Accurate flow quantification with echocardiography is an unmet clinical requirement especially in congenital heart disease. Pulsed-Wave Doppler (PWD) is widespread but has low accuracy and repeatability. 3D colour Doppler Images (3DCD) can be used to calculate angle-independent flow rate but lacks spatial and temporal resolution. The current gold-standard modality, phase-contrast Magnetic Resonance Imaging (PC-MRI), is expensive, requires general anaesthesia in infants. MRI has a long scan time for 3D imaging and is prone to motion artefacts. We propose an angle-independent, highly time resolved method for flow rate and volume quantification from multiview temporally interleaved 3DCD.

Methods:
Echo data was acquired on 4 patients with Hypoplastic Left Heart Syndrome post total cavopulmonary connection, using a Philips iE33 (X3-1) 3D probe. Angle-independent flow rate was obtained by integrating velocity over composite spherical surfaces computed from multiple 3DCD images (Fig. c). The surfaces are made of spherical patches which belong to different 3D views, allowing increased coverage and approximation to user defined surfaces. Increased frame rate was achieved by interleaving trigger-delayed acquisitions. Cardiac inflow and outflow were measured. For the inflow, 2 apical views were acquired covering the tricuspid valve. For the outflow, coverage was achieved with 1 view. In all cases, 3 delays were used in the echo acquisition: 0, 20 and 40ms. 3DCD images were acquired in 7 beats. The total duration of the echo exam was less than 10 min. Results were validated against flows from PC-MRI.

Results:
Results are in the tables (a-b) which show the relative error in inflow and outflow volumes with respect to PC-MRI, using single view, non interleaved 3DCD and the proposed multiview, temporally interleaved 3DCD. The table shows that the proposed method outperforms 3DCD with good correlation in volume quantification and an average error in estimation of flow volume below 10%.

Conclusions:
Standard approaches for flow quantification with Doppler lack accuracy due to angle dependency, temporal resolution and spatial coverage. We have proposed a method which compounds velocity values from multiple interleaved 3DCD images to calculate accurate, highly time resolved flow rate and flow volumes through user-defined surfaces.