Title: Measuring cardiac output *in-vivo* using through-plane velocities obtained from ultrasound speckle decorrelation

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Background, Motivation and Objective

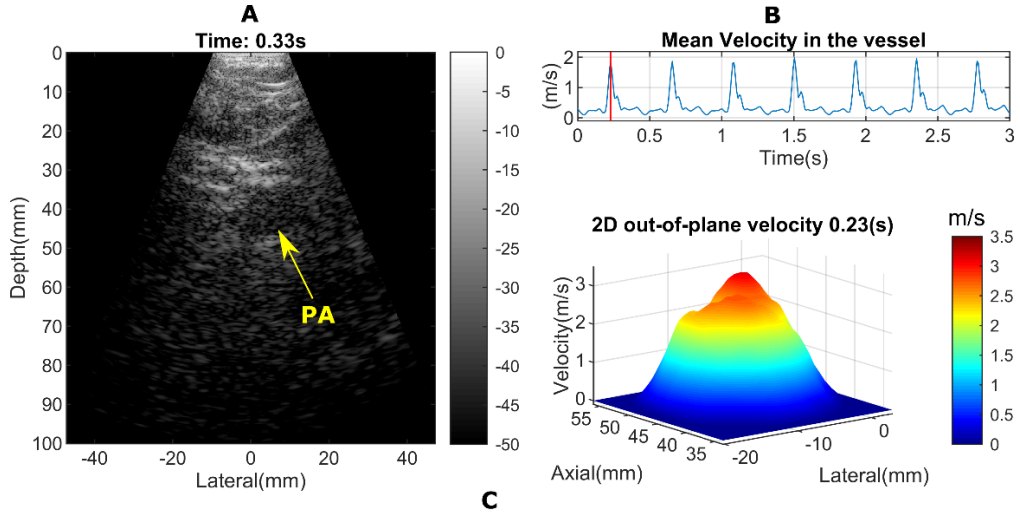
Cardiac output (CO), the blood exiting the left or right ventricle, is a key biomarker for evaluating cardiac function for both clinicians and researchers. Ultrasound allows for the non-invasive assessment of CO whilst patients are undergoing physiological testing. However, it remained as a challenge to measure the volumetric flow with a 1D array probe by only estimating the in-plane flow velocities. This study proposes calculating volumetric flow from through-plane spatially-resolved velocities using ultrasound speckle decorrelation (SDC). We demonstrate this is feasible in vivo from transverse views of the main pulmonary artery (PA).

Statement of Contribution/Methods

Ultrasound images were obtained with a Verasonics 128 system, using compound diverging wave (P4-2v probe, 3.5MHz, MI~0.15) ranging from -20° to 20° (7 angles, opening angle: 45°) and a scanning depth of 10 cm (PRF = 6600). A patient undergoing contrast (SonoVue) stress echocardiography (SE) as part of a clinical trial was recruited for this study. During SE, dobutamine was infused to increase the heart rate and contractility. Ultrasound data (3s per acquisition) of a transverse view of the PA were collected before (at rest) and after the administration of dobutamine. 2D through-plane velocities of the PA were estimated by analyzing the ultrasound SDC rate within the manually segmented luminal area. The relation between the decorrelation rate and the flow velocity was calibrated with a speckle phantom by mounting the probe on a motorized staging system.

Results/Discussion

The transverse view of human PA can be obtained by the ultrasound imaging (Fig.1A). An example of 2D through-plane velocity at a peak systole is shown in Fig.1B (lower graph), and the repeatable mean velocity over luminal area in Fig.1B (upper graph). The mean volumetric flow (equivalent to the CO) and the stroke volume of one cardiac cycle at three different phases (at rest; at peak stress; during recovery) are listed in Fig.1C. These results indicated that the CO can be measured from the main PA through a 1D array probe using the SDC method. Measurements at the proximal aorta would be equivalent, but it often lies at the depth limit of our current technique. Trials on more patients need to be conducted to prove the reliability of this method, and measurements from other methods might need to be used to further evaluate its accuracy in the future.



C

At rest (Heartbeat: 86 bpm)	At peak stress (Heartbeat: 140 bpm)	During recovery (Heartbeat: 112 bpm)
MVF = 5.13±0.22 L/min SV = 58.15±3.86 ml	MVF = 6.25±0.17 L/min SV = 44.73±1.57 ml	MVF = 5.62±0.11 L/min SV = 50.86±0.52 ml

Fig.1. (A):B-mode image of the PA under the transverse view; (B): at peak stress, mean velocity within the PA (upper graph), and visualisation of 2D through-plane velocity (lower graph) at the systolic peak indicated by the red line at upper graph;(C) comparisons of the estimated mean volume flow (MVF) and the stroke volume (SV) within one cardiac cycle before and after the administration of Dobutamine.