Left-ventricular blood-flow pattern estimation by low-rate dynamic contrast-enhanced ultrasound

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Background, Motivation and Objective

Left ventricular (LV) blood-flow patterns are strongly associated with the LV function. As such, visualization and analysis of the spatiotemporal distribution of these patterns may aid the diagnosis and management of LV dysfunctions. Current techniques for visualization of blood flow are typically based on speckle-tracking using ultrafast ultrasound acquisitions. Although few advanced systems offer 2D ultrafast imaging options, most clinical systems have limited frame rates, which is a general limitation for all 3D imaging solutions. Starting from 2D, we propose a novel technique to estimate LV blood-flow patterns by dynamic contrast-enhanced ultrasound (DCE-US) at low frame rates, which is also suitable for 3D imaging.

Statement of Contribution/Methods

23 Hz 2D DCE-US acquisitions were performed in 18 patients who underwent cardiac resynchronization therapy (CRT). Velocity vectors were estimated by combining time-delay estimates and inter-pixel distance vectors within a circular kernel. Since these vectors vary considerably across the cardiac cycle, we leveraged moving time windows to collect time-intensity-curve (TIC) samples from the same phase of subsequent cardiac cycles, determined by synchronized electrocardiography. Time delays were then estimated by maximizing the cross-correlation between each pair of time-windowed TICs. This procedure is shown in Fig. 1(a). The full LV velocity vector field was subsequently constructed by moving the kernel across the dynamically-contoured ventricle. The field components were then regularized and relative pressures calculated using a Navier-Stokes framework. Based on the estimated velocity and relative pressure, flow features related to ejection efficiency were derived and evaluated for their ability to distinguish between CRT responders and non-responders. The extension of this method to 3D DCE-US was also tested.

Results/Discussion

Fig. 1(b) shows the estimated blood-flow patterns during one cardiac cycle, which are qualitatively in line with the flow patterns based on the literature [1]. Relative flow feature variations before and after CRT evidenced a significant difference ($p<0.05$) between responders and non-responders for all the features. Fig. 1(c) shows an example of 3D estimation, evidencing the ability to process 3D DCE-US acquisitions at 3 Hz.

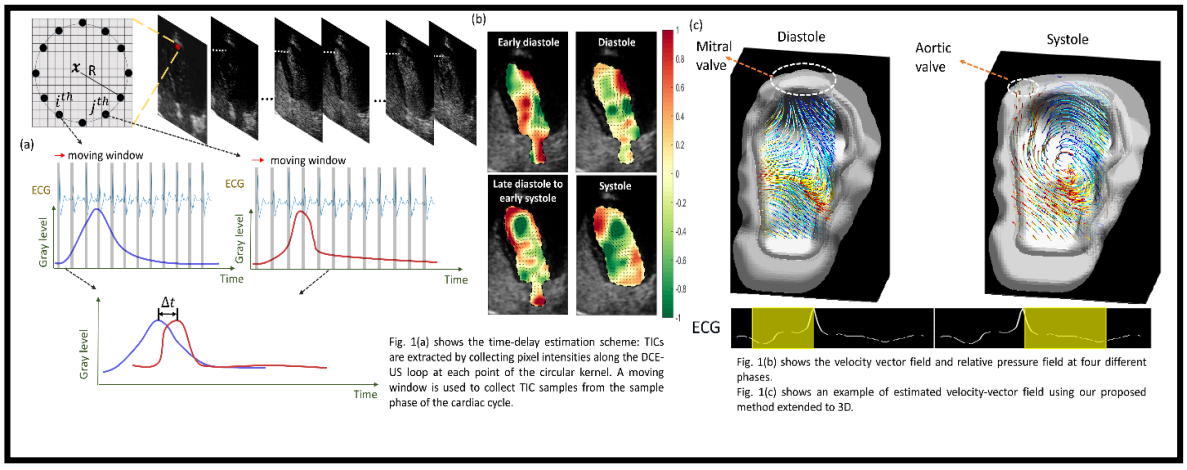

Fig. 1(a) shows the time-delay estimation scheme: TICs are extracted by collecting pixel intensities along the DCE-US loop at each point of the circular kernel. A moving window is used to collect TIC samples from the same phase of the cardiac cycle.

Fig. 1(b) shows the velocity vector field and relative pressure field at four different phases.
Fig. 1(c) shows an example of estimated velocity-vector field using our proposed method extended to 3D.

[1] Cimino et al., EUR J MECH B-FLUID, 2012.