The effect of high frame rate imaging methods in clinical color flow echocardiography

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Background, Motivation and Objective

Color flow imaging (CFI) is currently used in echocardiography for the qualitative detection of abnormal blood flows. Indeed, quantitative measurements are hampered by a compromise between frame rate and field of view. High frame rate (HFR) imaging techniques overcome this limitation at the cost of reduced image quality and penetration that, in turn, affects the quality of the flow estimates. The aim of this work was to compare the effects of different HFR methods in CFI while considering safety limitations for clinical applicability.

Statement of Contribution/Methods

A cardiac phased array (P4-2v) was connected to a Vantage 256 system (Verasonics) to scan a 90°-wide, 12cm-deep sector, with a Doppler packet size nP=8. Four scan modes were tested: single-line transmission (SLT) as benchmark; multi-line transmission with 4 simultaneously transmitted beams (4MLT); and diverging waves with 2 different opening angles, 2φ=20° (DW20) and 90° (DW90). Transmission voltages were preventively adjusted to obtain the same average electric output power (OP) for all modes. In reception, parallel beamforming was used to reconstruct 128-line frames. Acquisitions were performed on a flow phantom (CIRS); results were compared in terms of signal-to-noise ratio (SNR), size of the artifacts area (A%), relative error of the velocity estimates inside the tube (e%), probe heating after a 30-minute long scan (ΔT), mechanical (MI) and thermal (TI) indexes. In-vivo acquisitions were performed on healthy volunteers for a qualitative comparison.

Results/Discussion

Fig. 1 shows how artifacts spread across CFI frames both for phantom and in-vivo recordings. As shown in Table 1, DW90 has the largest artifacts area, whereas A% is 37%, 24%, and 53% lower for DW20, 4MLT, and SLT. HFR artifacts do not significantly affect velocity estimates in the tube as e% was reasonably low (<6%). In terms of SNR, 4MLT and DW20 perform similarly (−6/7dB w.r.t. SLT), whereas DW90 achieves the lowest SNR (−11.5dB). Since MI and TI were always well-below the safety limits, in a clinical setting, transmission voltages could be increased until ΔT reaches the safety limit of 10°C, thus improving SNR, especially for MLT.
In conclusion, both MLT and DW20 enable wide-angle CFI at higher frame rates (FR) than currently available. DW90 may boost FR up to 625 Hz (in continuous acquisition) by significantly compromising SNR.

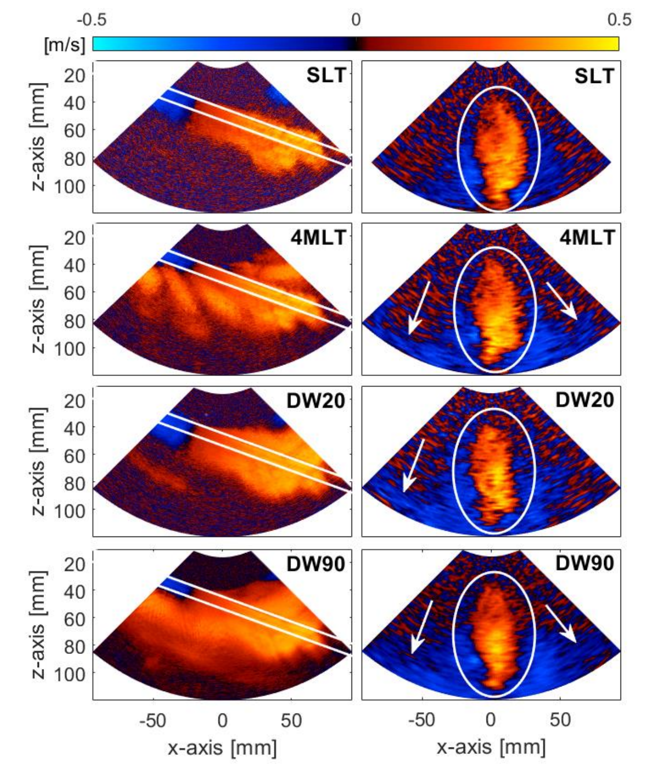

Fig. 1 – Examples of CFI acquired on the flow phantom (left) and in-vivo (right). The white parallel lines on the left correspond to walls of the tube. The ellipses on the right highlight the left ventricle and the arrows point to the artifacts do to mitral valve closure.

Table 1 – Comparison metrics.

	FR [Hz]	A% vs DW90	e% vs SLT	ΔSNR [dB]	MI	TI	ΔT [°C]
SLT	9.8	-53%	0%	0	0.37	0.76	6.4
4MLT	78.1	-24%	5.3%	-6.7	0.29	0.79	5.5
DW20	78.1	-37%	4.9%	-5.8	0.56	1.20	7.8
DW90	625.0	0%	5.9%	-11.5	0.23	0.45	7.0