Ultrafast radial modulation imaging

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Background, Motivation and Objective

Radial modulation imaging (RMI) improves the detection of microbubbles at high frequency [1-4]. Its principle is to use a low-frequency excitation to manipulate microbubbles diameter and a higher frequency excitation to image them. Imaging pulses are generated during rarefaction and compression peaks of the manipulation frequency before being subtracted to keep only signal from microbubbles. However, the synchronization between the imaging pulses in RMI is non-trivial and the time-delay difference due to dispersion of the imaging pulse have to be corrected [2, 5]. To simplify RMI process, we propose ultrafast radial modulation imaging (uRMI).

Methods

Diluted Sonovue (1/3000) was injected in a flow phantom (0-20 mL/min). It was insonified by two confocal transducers, one array at 15MHz and a single element at 1 MHz. The single element generated a continuous excitation close to 1 MHz (10-35 kPa). The array, controlled by a Verasonics Vantage, generated ultrafast acquisitions with plane waves (300 kPa, 1 cycle, PRF 1/60 µs, 1-7 compounding angles). Ultrafast radial-modulation imaging consisted in addressing the microbubbles at different stage of their oscillations using the beat frequency between the ultrafast imaging and the modulation. For each acquisition, 1000 images were acquired, demodulated by a lock-in amplifier (around the modulation frequency) and beamformed. The uRMI technique was compared to other techniques to detect microbubbles: amplitude modulation at 15 MHz, microbubble disruption and SVD filter.

Results/Discussion

The contrast-to-tissue ratios obtained with uRMI at 15 MHz were from 7.2 to 14.8 dB for the different conditions. It increased with the amplitude of excitation of the low frequency and with the number of microbubbles modulation-states and decreased with the flow speed. uRMI (10 dB) provided the best CTR without flow, higher than SVD filter (8 dB), microbubbles disruption (6 dB) and amplitude modulation (4 dB) (Figure 1). With flow, SVD filter provided the best CTR. The inherent limitation of uRMI and RMI is the decorrelation of microbubbles through a higher flow velocity or a lower frame rate.

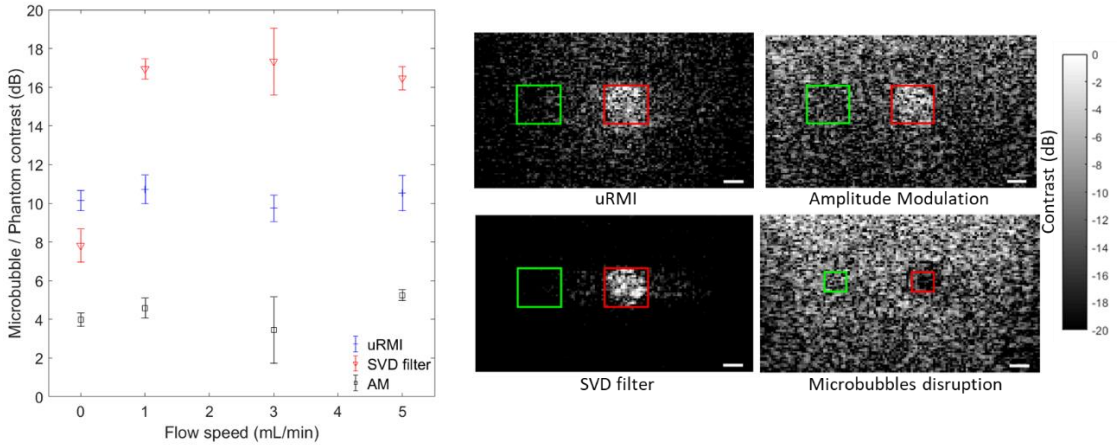

Figure 1. CTR as a function of flow speed for the different techniques and examples of images.

[1] Shariff HH et al, 2 006.
[2] Angelsen BA et al, 2007.
[3] Chérin E et al, 2008.
[4] Masoy SE et al, 2008.
[5] Hansen R et al, 2009.