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Visualization of subcutaneous flow tract using SVD filtering of ultrafast high-frequency ultrasound imaging

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1. Introduction

In the diagnosis of cutaneous disorders, visualization of vasculatures plays a pivotal role in the determination of the diseases. High-frequency ultrasound (HFUS) has been used in skin imaging to visualize the morphology and subcutaneous structures. However, visualization of vasculatures in HFUS b-mode imaging is challenging because of minute dimension of the vasculatures. These superficial structures can be visualized by mapping the blood flow signal using highly sensitive Doppler ultrasound imaging.

Recently, ultrafast Doppler imaging[1)] is gaining huge interest in detection of slow-time slow moving flow signal in vasculatures due to its higher spatio-temporal resolvability. Although, this technique has higher sensitivity to detect the slow-flow signal, but an efficient clutter filter is also required to extract the slow-time signal efficiently from the ultrafast Doppler data.

Demene et al[2)], reported in their study that the spatio-temporal clutter filter such as singular value decomposition (SVD) outperformed than the conventional temporal based clutter filter in the extraction of slow-time signal from ultrafast ultrasound data.

In this study, we devised an imaging framework, based on HFUS ultrafast imaging in order to achieve high resolution and highly sensitive images to extract the slow-time signal efficaciously by implementing SVD clutter filter which eventually assist in the visualization of subcutaneous vasculatures.

2. Materials and Methods:

2.1 Imaging System

A HFUS ultrafast imaging setup comprised of research purpose ultrasound imaging system (Vantage 256, Verasonics Inc., Kirkland, WA, USA) equipped with L38-22v CMUT (KOLO silicon, USA) linear array transducer was used for transmission and reception of ultrasonic signal. A straight tube PVA phantom of two different core dimensions (2 mm and 1 mm) at depth of 4 mm were designed and fabricated by following the protocol by Ho Chung et al[3)] and a flow setup which includes an infusion pump to infuse the flow of blood mimicking fluid at rate of (1.88 ml/min and 0.47 ml/min) with flow speed of 10 mm/s

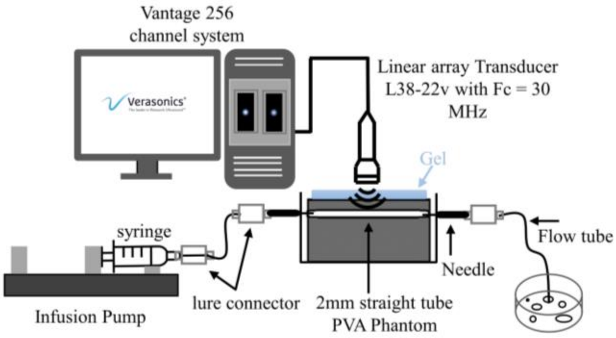

Fig. 1 Schematic diagram of an imaging setup to optimize the system for detection and extraction of flow tract in 2 mm and 1 mm PVA phantoms at flow speed of 10 mm/s by HFUS ultrafast Doppler imaging.

from the respective flow channels. A flow circuit assembly used (plastic tubes 2.5 mm, luer connectors 2.5 mm and 26 G needle) to connect the infusion-pump with flow tract and to pass the flow from the channel without any leakage as shown in **Fig.1**

2.2 Signal Acquisition and Processing:

The ultrafast Doppler signal was acquired and process from the respective flow tract, under two experimental conditions shown in **Tab.1** to evaluate the Doppler sensitivity of the devised imaging framework and the performance of the SVD clutter filter in extraction of slow-time slow flow signal.

Experimental Condition 1		Experimental Condition 2	
Data Acquisition		Data Acquisition	
Doppler Ensembles	14	Doppler Ensembles	35
Plane wave Imaging	No Compounding	Plane wave Imaging	(3 angles) Compounding
Processing		Processing	
Clutter Filter	Regression	Clutter Filter	SVD

Tab.1. Data acquisition parameters under two experimental conditions to evaluate the Doppler sensitivity of the devised imaging framework.

2.2.1 Experimental Condition 1:

In the acquisition of the signal, 128

channels of the transducer were excited at 30 MHz of center frequency to transmit the plane wave pulses (3 cycles) at pulse repetition frequency (PRF) of 3 MHz, and 14 Doppler ensembles were acquired to process by implementing regression clutter filter of second order (quadratic basis) to extract the signal from the respective flow tract.

2.2.2 Experimental Condition 2:

Instead of transmitting single plane wave, 3 plane waves were transmitted which were coherently compounded at the reception to quantify the intensity of the signal content. The acquisition parameters were same as in condition 1, except the size of the Doppler ensembles were increase from 14 to 35 ensembles. Also, to estimate the significance of the clutter filter in the extraction of slow-time signal, the acquired ultrafast data was processed by implementing singular value decomposition (SVD) clutter filter.

3. Results

The power Doppler images obtained from two experimental conditions presented in **Fig.2** shows that the coherently compounded and higher ensemble size of ultrafast data increases the intensity of the Doppler signal. **Fig.2(a)** shows the power Doppler images of 2 mm and 1 mm flow tracts, have poor intensity of the detected signal which is acquired with plane wave along with lower ensemble size and processed with regression clutter filter. Whereas in **Fig.2(b)** the detected signal has higher intensity which is processed with SVD clutter filter.

Moreover, From the quantitative measurements shown in **Fig.3**. It was observed that the signal-to-noise ratio (SNR) of the detected signal is higher when the data is acquired with ultrafast compounding and higher number of Doppler ensembles. This measurement indicates that the Doppler sensitivity of the framework in detection of slow-time signal depends on the number of acquired ensembles as well as the compounding angles which enhances the signal quality.

4. Conclusion:

In this study, we devised an imaging framework to extract the slow-time slow flow signal by implementing an SVD clutter filter. Qualitative **Fig.2** and Quantitative **Fig.3** measurements indicates that the devised imaging framework has improved performance to detect the signal from respective flow tract (2 mm, 1 mm) at depth of 4 mm by ultrafast compounding technique and SVD filtering. Based on these observations, it can be utilized in the visualization of *in-vivo* subcutaneous flow tract by further optimizing the system acquisition parameters.

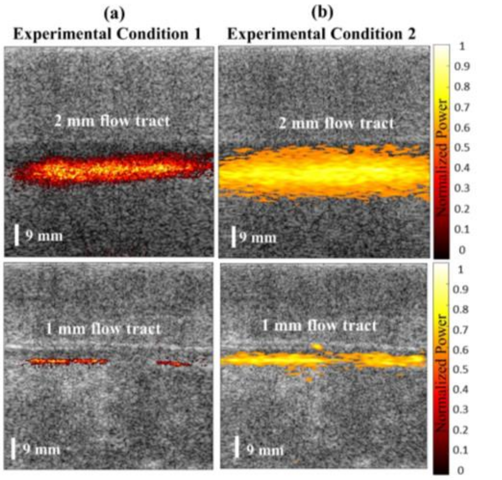

Fig. 2 Power Doppler images obtained by two experimental conditions. (a) Experimental condition 1. (b). Experimental condition 2.

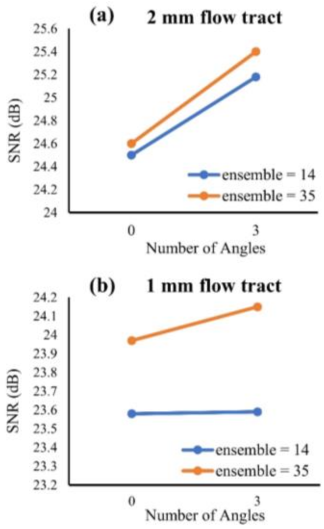

Fig. 3. Signal-to-noise ratio (SNR) measurement of plane wave, plane wave compounding, small number of Doppler ensembles, and higher number of Doppler ensembles. (a). SNR measurement from 2 mm flow tract. (b). SNR measurement from 1 mm flow tract.

References

1. H. C. Li, P. Y. Chen, H. F. Cheng, Y. M. Kuo, C. C. Huang: IEEE Trans Ultrason Ferroelectr Freq Control **66** (2019) 3393.
2. C. Demene, T. Deffieux, M. Pernot, B. F. Osmanski, V. Biran, J. L. Gennisson, L. A. Sieu, A. Bergel, S. Franqui, J. M. Correas, I. Cohen, O. Baud, M. Tanter: IEEE Trans Med Imaging **34** (2015) 11.
3. C. K. Ho, A. J. Y. Chee, B. Y. S. Yiu, A. C. O. Tsang, K. W. Chow, A. C. H. Yu: IEEE Trans Ultrason Ferroelectr Freq Control **64** (2016) 25.