In vivo Visualization of Human Venous Vortex Flow by Using High-Frequency Vector Doppler Imaging (HFVDI)

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Background, Motivation and Objective

Chronic venous insufficiency can be diagnosed by Doppler ultrasound imaging. In most cases, ultrasound imaging with a frequency range of 3–13 MHz is used to measure the flow conditions of low extremity veins for CVD. However, high-resolution ultrasound imaging is still required for superficial veins because the anatomical structure between the valve and venous wall is very small. In this study, high frequency ultrasound (HFUS) vector Doppler imaging (HFVDI) was implemented by using the 40 MHz ultrafast ultrasound imaging to visualize the human venous vortex flow.

Statement of Contribution/Methods

Experiments were performed on the superficial veins of the thighs from healthy volunteers. A HFUS system (Verasonic Vantange 256) with a 40 MHz liner array transducer (Visualsonics MS550D) was used for data acquisition. 128 active elements and three plane-wave tilted angles ($\pm 5^{o}$) were used for measurements. The PRF was 1500 Hz. A high-pass filter with a cutoff frequency of 10 Hz were used to eliminate tissue noise. HFVDI was performed by the multi-beam Doppler method. The phase-unwrapping methods based on the spatial and temporal continuities was implemented to avoid the aliasing problem due to HFUS application.

Results/Discussion

Figs. 1(a) and (b) show the HFVDI of human venous flow when the valve was opening and closing, respectively. Figs. 1(c) and (d) show the corresponding images in the valve cusp area. The arrow represents the flow direction, and length of arrow represents the absolute velocity. Also, the color map shows the flow direction. When the valve was opening, the flow direction was from left to right as well as the vortex flow was observed easily in Fig. 1(c). The direction of flow reverse and the vortex was also formed when the valve was closing. The mean velocities between the leaflets of valves were 14.4 ± 9.5 and 6.6 ± 2.5 mm/s when the valves were opening and closing, respectively. Because of the high resolution of HFVDI, the jet and vortex phenomena were observed between the leaflets and in the sinus pocket, respectively. Flow velocities ranging from 2 to 15 mm/s were measured at different locations around the venous valve during the opening and closing phases. All the results indicated that HFVDI has the potential to be a useful tool for vessel duplex scanning in the future.