Vector flow imaging of graded artificially-induced complex flow in the human femoral artery bifurcation

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Background, Motivation and Objective

Multi-directional flow, which may emerge in the femoral artery bifurcation, may contribute to a pro-atherogenic hemodynamic environment. One way of transiently inducing these complex flow patterns in humans is to manipulate the peripheral vascular resistance through external compression, although their complexity cannot be quantified with conventional ultrasound. The purpose of this study was to examine the impact of graded increases in peripheral resistance on complex flow at the femoral bifurcation using high frame rate ultrasound (HiFRUS). We hypothesized that HiFRUS would allow quantification of flow complexity in order to better study complex hemodynamic environments *in vivo*.

Methods

Six healthy adults (26±4 years of age; 4 women) participated in this study. The femoral bifurcation was imaged using HiFRUS (US4US; SL1543 probe; 6 kHz PRF; Tx˚ -10, 10), while common femoral, superficial femoral (SFA), and deep femoral artery (DFA) blood velocities were acquired with a clinical ultrasound unit (Phillips iE33; L9-3 probe). A pressure cuff was placed around the calf and inflated at 0, 20, 40, 60, 80, and 100 to change the resistance of the SFA. Seven transmit-receive angle pairs were used to derive vector flow images (750 fps), which were subsequently dealiased with an extended least squares approach. Vector complexity was characterized by the resultant angular vector dispersion, which scales from 0-1, with lower values indicating complex flow.

Results & Discussion

During compression, DFA and SFA flow reversal did not emerge concurrently, which created multi-directional flow within the same arterial segment (Figure). At 100 mmHg compression, retrograde blood velocities increased from baseline in the SFA (-27.8±10.8 *vs.* -50.1±7.2 cm/s; P<0.001). Similarly, peak diastolic flow complexity was increased by 100 mmHg (0.83±0.03 *vs.* 0.58±0.11; P<0.001), likely due to the divergent SFA and DFA flow directions. These results show that HiFRUS-based vector flow imaging can effectively quantify transient complex flow induced via experimental manipulation of downstream peripheral resistance. This tool may be further applied to examine the consequences of chronic exposure to multi-directional flow and bifurcation complexity, such as during prolonged sitting in healthy adults, or in the presence of peripheral artery disease.

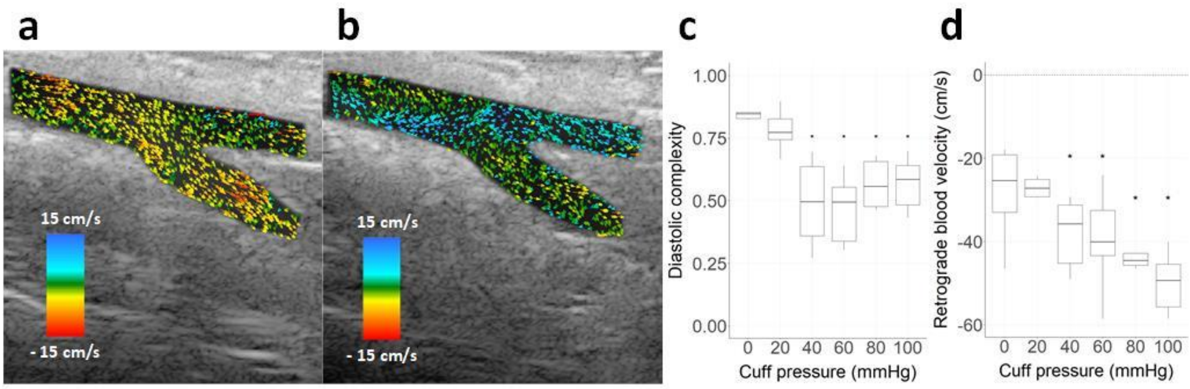

FIGURE. Vector projectile images of a representative femoral artery bifurcation in early diastole at baseline (a), and 100 mmHg (b) cuff compression at the calf. Flow complexity increased with cuff compression (c), mirroring increases in the magnitude of retrograde blood velocity (d). *P<0.05 *vs*. baseline