Adaptive method for velocity vector imaging in the carotid bifurcation

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Background, Motivation and Objective

Visualization and quantification of blood flow is considered an important tool for assessing development of atherosclerosis and patient-specific diagnosis and intervention. As conventional Doppler imaging is limited to 1D velocity estimates, 2D and 3D techniques are being developed. With the aim of capturing complex flow patterns associated with plaque development and progression, this study shows an improved version of our velocity compounding method. The main novelties are the adaptive nature of the velocity compounding, the adaptive effective PRF, and the adaptive clutter filter.

Statement of Contribution/Methods

We performed angled plane wave ultrasound acquisitions (-20° and 20°) at 8000 Hz using a 7.8 MHz linear array transducer connected to a Verasonics Vantage 256 system. Adaptive clutter filtering was performed, which velocity cut-off point was set dynamically based on tracked vessel wall velocities. Inter-frame displacements were estimated using a 2D cross-correlation-based algorithm with temporally adaptive PRF for improved accuracy. Subsequently, 2D blood velocities were obtained by either compounding both angled axial displacement estimates, or by projecting single-angle 2D estimates when RF signal power and velocity variance of the other angle were not sufficient. The performance of the method was evaluated experimentally using a straight tube flow setup. Thereafter, initial in vivo evaluation was performed in healthy carotid arteries (n = 2), early-stage stenosed arteries (n = 1) and arteries after endarterectomy with stent placement (n = 2).

Results/Discussion

Straight vessel experiments demonstrated the technique performed with a maximum velocity magnitude bias of -3.7% (2.8% standard deviation) and an angle bias of -0.16° (0.41° standard deviation). In vivo, complex flow patterns were visualized in both healthy and diseased carotid arteries (Fig. 1A). In patients, these complex flow phenomena were more prominent than in healthy volunteers. Quantification of the complexity of the velocity field showed potential to distinguish these two groups (Fig. 1B). This information might provide clinicians with a new tool that aids in the assessment of the condition of the blood vessel and potentially allows for earlier detection of atherosclerosis.

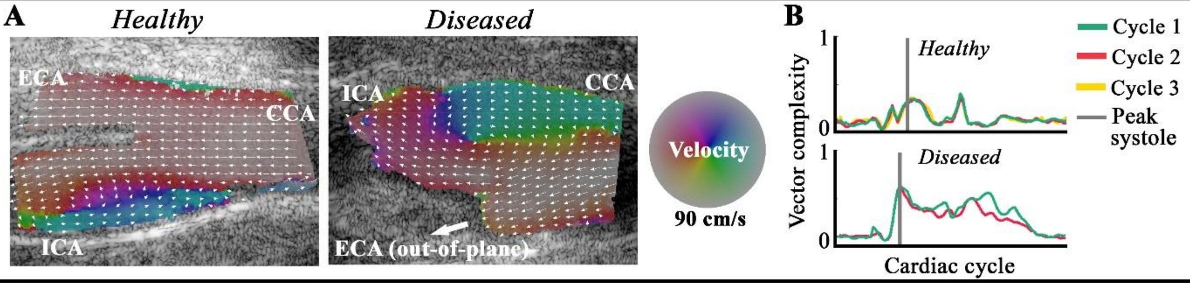

Fig. 1. A. 2D velocity vector fields in a healthy and diseased (after endarterectomy) carotid artery bifurcation. Frames visualized were obtained at peak systole. Complex recirculating patterns were visible in both volunteers.
B. Vector complexity as a function of time. Increased vector complexity values were found in the diseased artery.
ICA: internal carotid artery, ECA: external carotid artery, CCA: common carotid artery