Microbubble bolus kinetics of velocity segmented vasculature

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Background, motivation, and objective: The quantification of contrast enhanced ultrasound is an active area of research especially in the context of therapy monitoring. The most widely used quantification approaches, bolus-transit and flash-replenishment methods, have relied on conventional nonlinear imaging to follow changes in microbubble concentration over time, where no distinction is made of the distribution of differing velocities of microbubbles. In this work, we use plane-wave nonlinear Doppler acquisitions with singular value decomposition (SVD) processing to follow the microbubble bolus kinetics through different levels of the vasculature based on segmentation of blood flow velocity.

Statement of contribution/methods: We developed an approach enabling segmentation of blood flow at different levels of the vascular tree ranging from the microcirculation to larger vasculature utilizing ultrasound contrast agents. Using an ultrasound research platform (Verasonics Vantage, USA) combined with a 15 MHz linear array transducer, plane-wave amplitude modulated plane-wave Doppler sequences were implemented to follow the passage of a microbubble bolus. The sequence consisted of 40 nonlinear Doppler acquisitions (PRF of 1 kHz) repeated at a frame-rate of 16 Hz over 1 minute. SVD of each plane-wave nonlinear Doppler acquisition segmented microbubble flow of differing velocities.

Results/Discussion: Figure 1 illustrates the passage of a microbubble bolus through contused spinal cord tissue at different levels of the vascular tree based on SVD velocity projections. The top nine images show the wash-in of microbubbles for three SVD projections, with the hypoechoic region being disrupted vasculature from the contusion. Varying spatial distributions of both flow and bolus kinetics is observed for each of the three velocity components (i.e. perfusion, mid-flow, vascular flow). For the white matter (Fig. 1k), the vascular flow signal arrives before the flow in the lower velocity projections, which would bias conventional CEUS arrival time estimates. We have demonstrated the ability to seperate different components of low and high velocity blood flow and observe their differing bolus kinetics, enabling visualization and potential quantification of blood flow not previously possible with Doppler or CEUS methods.

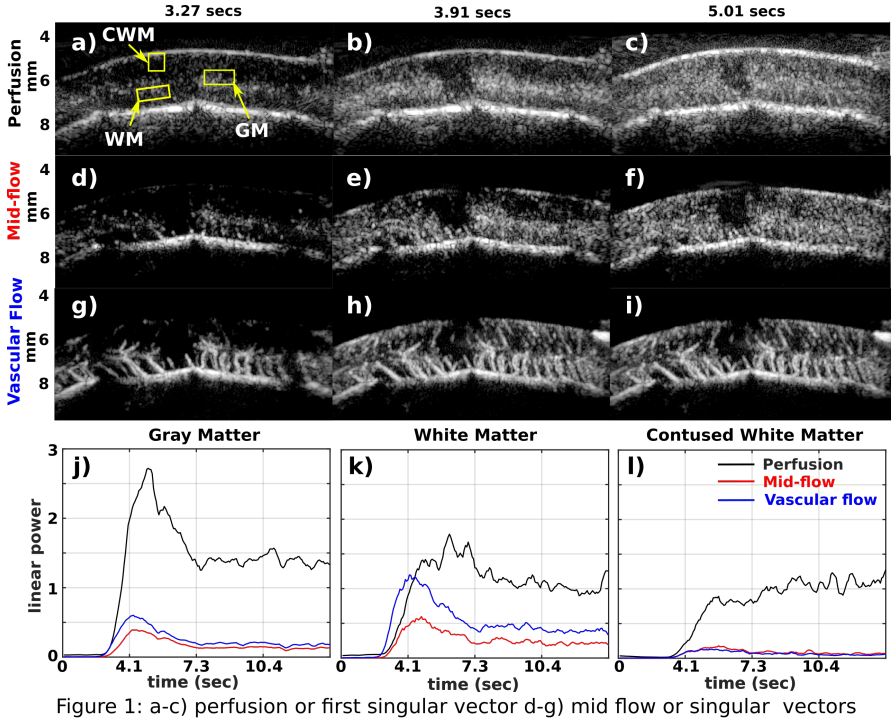

Figure 1: a-c) perfusion or first singular vector d-g) mid flow or singular vectors (4-5) g-i) vascular flow or highest singular vectors. j-l) time intensity plots of the three ROIs labeled in a) for the three groups of flow singular vectors.
ROI labels in a): GM-gray matter, WM-white matter, CWM-contused white matter.