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GPU-ACCELREATED PATIENT-SPEIFIC COMPUTATIONAL FLOW — FROM RADIOLOGICAL IMAGES TO IN VIVO FLUID DYNAMICS

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Summary: *We present a unique and efficient computational methodology to non-invasively quantify in vivo fluid dynamics and wall shear stress in human body based on CT/ MRI and Ultrasound images. Mesoscale lattice Boltzmann models for anatomical extraction and flow simulation and GPU acceleration are seamlessly integrated in one computational platform thus neither data transformation and mesh generation nor remote supercomputing required to achieve fast computation within clinically accepted time for medical diagnose and assessment. Although validation and demonstration have been focused on computational hemodynamics in cardiovascular system, the computation methodology is applicable to airflow, urinary flow, and peristalsis in other human systems as well.*

Background Blood flow hemodynamics has been established as a contributing factor for the development of atherosclerotic plaque [1] as interactions between an internal blood flow and wall deformation often underlie biological function or dysfunction of an artery. Patient-specific computational hemodynamics (PSCH), utilizing Computed Tomography (CT) or Magnetic resonance imaging (MRI) scanning data together with Ultrasound (US) measurements, has emerged [2-4] as an appropriate and powerful research tool to quantify 4-D (space and time) *in vivo* hemodynamics and blood-vessel interactions, that other research methods may not be capable, to reveal the influences in plaque formation [5] so that clinicians can better understand the hemodynamic behavior of different surgical options for treated patients [6].

Methodology We present an innovative mesoscale modeling and GPU (Graphic Processing Unit)-accelerated computational methodology for PSCH based on CT/MRI image data

(morphology) together with US records (inlet and exit flow conditions) from clinical evaluations. Image processing for anatomical extraction and fluid dynamics are modeled on mesoscale level using simplified and volumetric lattice Boltzmann methods [7-8] respectively. The models are seamlessly integrated and GPU parallelized on a unified computational platform. The research is novel in two aspects: (1) no explicit data reconstruction and mesh generation are needed avoiding extra computational cost and inaccuracy; (2) explicit algorithm and local data access of mesoscale modeling makes high efficient parallelization possible using cutting-edge GPU technology. This computational tool, featured external software and remote supercomputing free, is expected to solve realistic PSCH in clinic practice.

Validations A pulsatile velocity profile from PSCH agrees reasonably well agreement with US image analysis. In two application studies, steady flows in normal and dilated aortic arteries and pulsatile flow in a stenosed carotid artery capture typical velocity skewness and vortex pairs of blood flow. Flow pattern and vortex structure are seen much more complicated in diseased than healthy aortic artery. Wall shear stress (WSS) distributions on carotid artery wall consistently exhibit geometry-based high and low WSS zones in a pulsation.

Impact The GPU-accelerated unified computing platform will (1) enable secondary analysis of existing medical images from clinic via massive PSCH and parametric analysis aimed to identify unprecedented hemodynamic indicators for clinical assessment and prediction of fatal cardiovascular diseases such as stroke and heart attack and (2) facilitate access of medical practitioners to the quantitative flow information in diseased arteries simultaneously with CT/MRI imaging for lesion diagnose and assessment.

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