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Towards a Fast Dynamic Model of the Human Circulatory System

CAROLYN KAPLAN, MELISSA GREEN, JAY BORIS, ELAINE ORAN, Naval Research Laboratory — We describe a model for systems-level transport in the human circulatory system that is based on a set of equations for a one-dimensional unsteady elastic pipe flow circuit. The system is collapsed from three spatial dimensions and time to one spatial dimension and time by assuming axisymmetric vessel geometry and a parabolic velocity profile across the cylindrical vessels. To drive the fluid, the contractions of a beating heart are modeled as periodic area changes of the elastic vessels. Two different models are compared, both including and neglecting fluid acceleration. Time-resolved distributions of pressure, velocity and area compare reasonably well with reference data. Increasing the rigidity of the vasculature is found to increase peak arterial pressures on the order of ten percent, and including a distributed vascular contraction to model distributed skeletal muscle contractions monotonically increases time-averaged blood flow in the veins, consistent with human physiological response. The circulatory system model presented here simulates the circulatory system on the order of one hundred times faster than real-time; that is, we can compute thousands of heartbeats per minute of CPU time.

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