Particle-Laden Hemodynamics for Strokes

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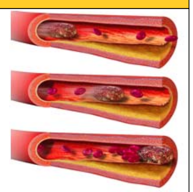
Abstract

Every year in the United States an estimated 800,000 strokes occur and of those an approximated 87% are classified as ischemic[1]. While strokes are of a major concern especially with an aging population, due to the complicated nature of blood, very little is known about its flow behavior, hemodynamics, and emboli trajectories once they are introduced to the circulatory system. By analyzing the circulatory domain of atrial to pre-capillary vessels, we are able to generalize the behavior of blood to being that of an incompressible, Newtonian Fluid and apply it to state of the art Computation Fluid Dynamic (CFD) simulations and techniques. In doing so we are able to produce profound and invaluable information regarding the factors present in the predilection of particles as they traverse the complicated vessel system from heart to brain, resulting in potentially catastrophic stroke and subsequent brain injury.

Goals of Research

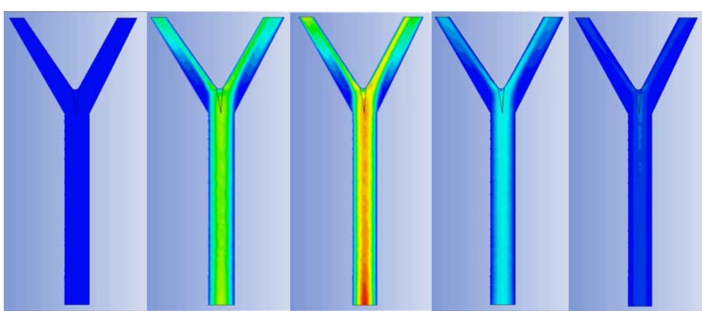
- Develop a more complete understanding of underlying mechanics of blood flow and how emboli traverse the circulatory system
  - How does emboli size affect trajectory?
  - How does geometry of vessels affect trajectory?
- How does coupling factors affect emboli predilection?
  - At what emboli sizes does one-way and two-way coupling produce different results?



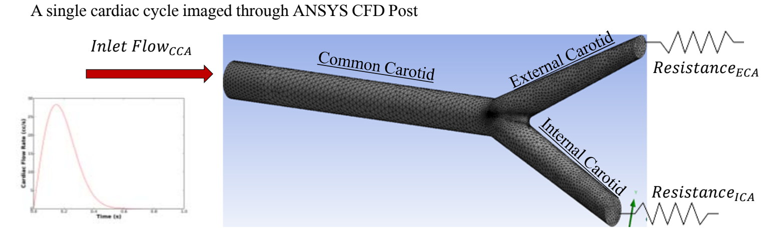
Blausen, Bruce. "Embolus." *Wikipedia*. Wikimedia Foundation, 07 July 2014. Web. 04 Aug. 2014.

Experimental Methods

- Idealized Y-Bifurcation of the CCA and its bifurcation into the ECA and ICA
  - Anatomically correct dimensions and parameters[2]
  - Pulsatile cardiac inflow and outlet resistances
- ANSYS Fluent 15.0
  - CFD Solver using Finite Volume Method
  - Injection of Particles of sizes (500, 750, 1000 and 1250 μm)
    - Radial Distribution
    - Random Distribution



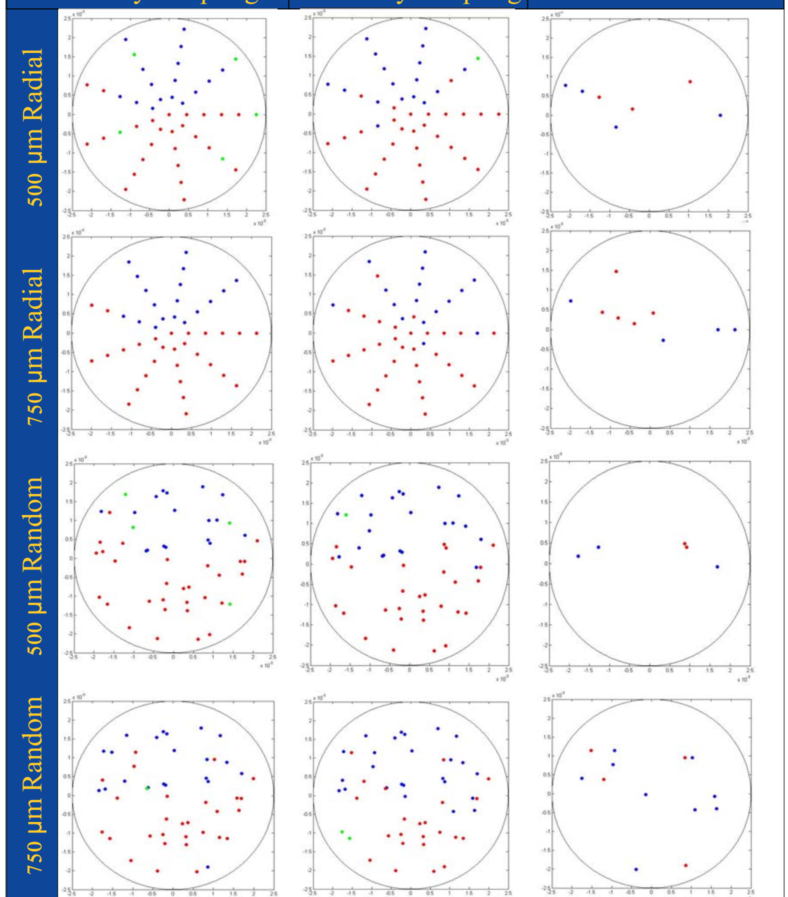
A single cardiac cycle imaged through ANSYS CFD Post



Anatomical 3D model of the common carotid bifurcation accompanied by pulsatile inlet flow and resistive boundary conditions

Results

Red=Internal Carotid Artery
Blue=External Carotid Artery
Green=Stuck/Not Converged



Coupling Type	Particle A (500 μm) Radial	Particle A (500 μm) Random	Particle A (750 μm) Radial	Particle A (750 μm) Random
One-Way	Distribution Percentage: 56.86% IC : 31.37% EC	Distribution Percentage: 58% IC : 34% EC	Distribution Percentage: 64.71% IC : 35.29% EC	Distribution Percentage: 56.0% IC: 42% EC
Two-Way	# of Different Trajectories 7 of 51	# of Different Trajectories 5 of 50	# of Different Trajectories 9 of 51	# of Different Trajectories 13 of 50

Conclusions & Discussion

- Particle distribution was relatively similar to that of expected values for particle sizes
  - Particles of smaller diameters were distributed at flow rate
- Differences between one and two way coupling was more than expected for particle size
  - Because particle influences fluid in two-way coupled simulations trajectories are producing different predilection destination
- ANSYS Flow Solver
  - Particle-Wall collision can be defective with allowing penetration up to a radii of the particle
  - Discrete Phase Model user defined function additions
- Future Simulations
  - Patient Specific Common Carotid Bifurcation
  - Patient Specific Full Aortic Arch

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2.Alastruey, J. and Parker, K.H. and Peiro, J. and Byrd, S.M. and Sherwin, S. J.(2006) Modelling the circle of Willis to assess the effects of anatomical variations and occlusions on cerebral flows. Journal of Biomechanics. Elsevier.

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