Two Dimensional Blood Cooling Model Inside a Carotid Bifurcation

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Abstract

Stroke according to the World Health Organization in 2011 was the number two leading cause of death worldwide; survivors of stroke will suffer permanent disabilities from brain tissue death [1]. Therapeutic hypothermia is a new treatment that reduces a patient's temperature to induce mild to moderate levels of hypothermia (2-5°C reduction in core temperature) at specific organs. Published research has acknowledged that even mild levels of hypothermia can reduce tissue death [2, 3, 4, 5, and 6]. A unique blood cooling catheter may synergize with current stroke treatments and has delivered rapid brain tissue cooling - up to a 8°C reduction in under 5 minutes during canine testing [7]. Current models approach the problem from a physiological and clinical perspective while using a simplified quantitative engineering model that cannot precisely predict discrete tissue temperatures [8], [9]. Creating a computational fluid dynamics heat transfer model of arteries near and in the brain will allow for a discrete prediction of temperature distribution of surrounding tissue during therapeutic hypothermia. This will allow for an accurate prediction of the effect that delivered fluid temperature and flow rate have on surrounding tissue. A two-dimensional CAD model is imported into COMSOL taking advantage of LiveLink™ capabilities. The model (based on dimensions of the human carotid artery) consists of a mock artery with a single bifurcation with each daughter branch having varied dimensions, as shown in Figure 1. A single catheter placed along the centerline before bifurcation injects cooled blood into the parent artery. The model is placed under pulsatile flow inlet conditions mimicking flow waveforms typical to the artery. COMSOL's ability to easily import data from tabulated values and repeat as a waveform is crucial in defining inlet conditions of the model. COMSOL fluid and heat transfer modules will be used to provide predictions within the model on varying fluid temperature and flow rates from the catheter. Mesh density and element size will be determined through the use of a mesh study in COMSOL. Boundary conditions to be considered parametrically: 1) Wall temperature 2) Catheter inlet temperature 3) Catheter inlet flow rate 4) Pulsatile waveform 5) Internal heat transfer coefficient. Upon completion of modeling, expected results are a prediction of temperature, velocity, and pressure distributions along the length of the model. Outlet fluid temperature in both bifurcation branches with varying durations, inlet catheter temperature, and flow rates will be predicted. By predicting temperature distributions at the outlet daughter branches as a function of duration, inlet catheter temperature, and flow rates ongoing research can be advanced into 3D modeling. This will allow for a more accurate physiological representation of further bifurcations and temperature distribution in surrounding brain tissue. This research will inform 3D Model outcomes with guide operational parameters and design features for a localized brain tissue cooling device.

Reference

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Figures used in the abstract

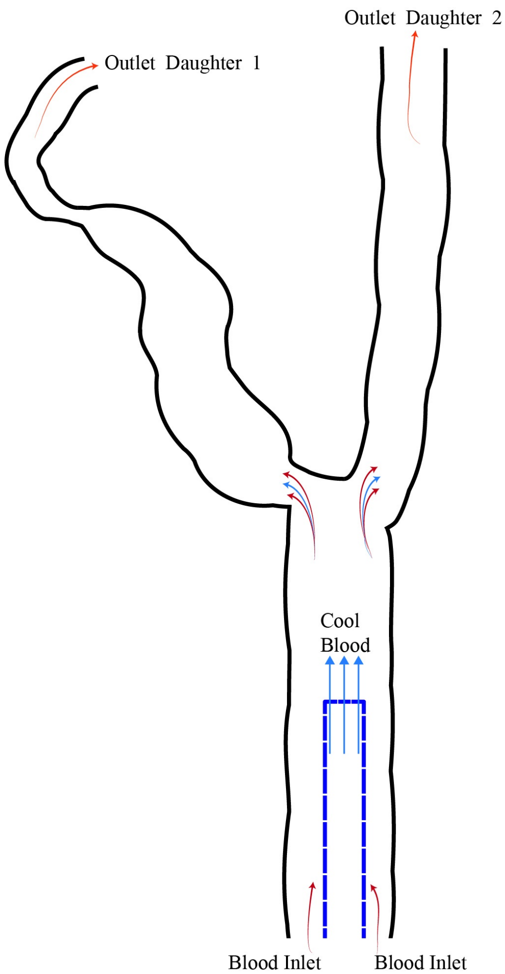

Figure 1: A model of the proposed mock artery, showing blood entering the carotid artery and cool blood through a catheter.