Sneak routes: how well can arteriolar arcades protect tissue perfusion?

Modeling the microcirculation

An internship position is available at the Biomedical Engineering and Physics department of the Academic Medical Center (AMC). In our group, new treatment and diagnostic procedures based on innovative physical techniques are developed. Research is performed by a multidisciplinary team that includes physicists, engineers, mathematicians, medical doctors, biologists, and chemists.

Background

Delivery of oxygen to all organs in our body depends on the presence of an extensive network of arteries, branching from the major arteries to the smallest vessels and including hundreds of millions of vessel segments. If an artery becomes obstructed by a small blood clot, the downstream tissue cannot be oxygenated and would die. Yet, nature has invented sneak routes (collaterals and vessel loops), such that tissue can be perfused from multiple entrances, much like your street, neighborhood or town being accessible from multiple entrances. It now seems that the degree of collateralization is highly variable between persons, and we suspect that the ill-collateralized are more susceptible for small infarcts, which initially may remain unnoticed but would add up to continuous decline of organ function. For the brain, we believe that this leads to chronic cognitive impairment and some forms of dementia. For the heart, far less is known about this.

The purpose of this internship is to better understand how sneak routes can protect perfusion in the presence of continuous micro-occlusions. From a physics/engineering point of view, the arterial system can be seen as a large network of resistances, their values and connectivity determining local flows and pressures. We have detailed data on this, allowing building models and testing the effect of occlusions and presence of more or less sneak routes.

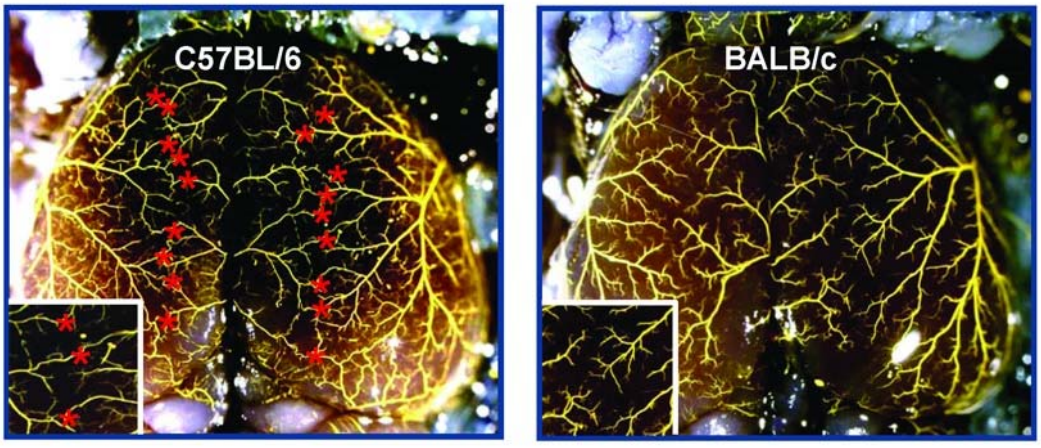
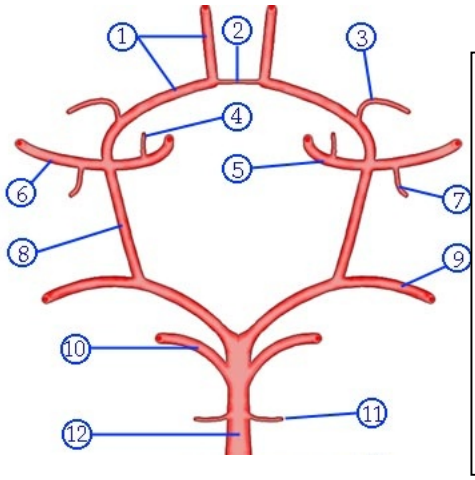


Image of the surface of the brain of two mice. Arterial trees coming from two main entrance roads (1 and 6 in the next figure) are connected by collateral vessels (red stars) for the left one, but not for the brain on the right (from ref 1).



Schematic drawing of the large vessels at the base of the brain. Flow from the heart enters this 'Circle of Willis' from 5 (carorid arteries) and 12 (basilar artery). The circle, like the Amsterdam A10 ring, then distributes flow to vessels that perfuse the brain (1, 6, 9 and others). This circle is not always complete, e.g. 8 is missing in some people, who as a consequence get much more brain damage if 5 is obstructed. Such arcading networks are found at various scales in the brain, heart, and other organs.

Research description

In this project you will:

1. Set up a computer model of the branching and arcading network, based on data obtained on human or animal hearts. These data include the diameter and length of millions of segments and a description of the way they are connected.
2. Implement routines for calculating local pressures and flows, based on straightforward linear analysis.
3. Use these routines to test a range of scenarios, such as the blocking of vessel segments by micro-emboli.
4. In a possible extension, make these models adaptive, accounting for the observed growth and shrinkage of arterial segments when they are carrying respectively more and less flow.

A more detailed research plan will be made when you start, and this plan will depend on your interests, curriculum (Ba or Ma) and length of your internship.

Requirements

We are looking for a Bachelor or Master student with a physics/mathematics/engineering background and an interest in the cardiovascular system. Programming skills or the willingness to acquire these during the internship are mandatory. Programming will be done in Lazarus or Matlab. The duration of the internship can be adjusted according to the curriculum.

Learning outcome

You will gain knowledge in the field of cardiovascular physics and engineering, and will learn how to translate a clinical problem to a technical analysis. You will develop programming and computer modeling skills. Being part of an interdisciplinary and international research group you will acquire competences including: (1) collaboration, (2) scientific writing, and (3) presentations.

References

1. Wang S1, Zhang H, Dai X, Sealock R, Faber JE. Genetic architecture underlying variation in extent and remodeling of the collateral circulation. Circ Res. 2010 Aug 20;107(4):558-68.

Contact

Name: Ed van Bavel, Professor of Vascular Biophysics
Email address: e.vanbavel@amc.uva.nl www.amc.nl/bmep