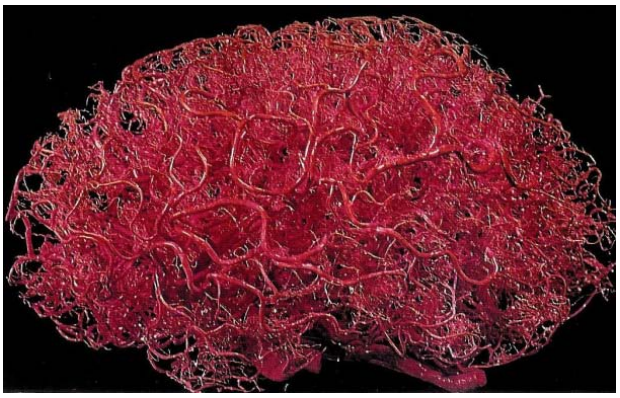
Blood flow regulation in vascular network

A modeling study

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.

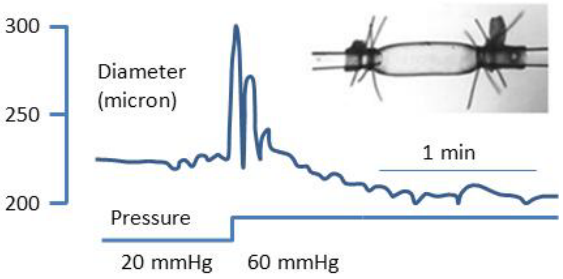
Background

The human body contains some 100 million arterial segments, with diameter varying 10.000-fold between the aorta and the precapillary arterioles. All these vessels together distribute and regulate blood and oxygen to each and every cell in our body. This is a unique system, where each of the vessels 'knows' which diameter to maintain. Such diameter regulation is based on sensing of mechanical stimuli (related to pressure and flow), hormones, neural input, but also by electrical communication between connected vessels. Yet, the system doesn't always work perfect, leading to amongst others high blood pressure, heart failure, and cognitive decline. Within the research line Vascular Biophysics, we study the function and failure of such networks.



The branching pattern of arteries in the brain

Every segment in the network controls its diameter at a temporal scale of seconds to months by a range of mechanisms. Constriction and relaxation of vascular smooth muscle cells form the fast response[1,2]; the image below shows a so-called myogenic response to increasing pressure. The long-term response is reorganization of the wall material (cells, matrix) and finally gain or loss of tissue[3]. These responses are linked: any short-term response changes the stimulus for long-term regulation, and vice versa. In order to really understand this complexity, simulation models are needed that integrate the responses. We made such a model for a single segment. In addition, we have data and models on branching patterns of vascular networks[4]. The challenge is to combine the two; to build network models in which each segment regulates its diameter. This is where you come in!



A single artery, maintained alive and mounted between two glass pipettes that allow pressurization and perfusion. A step increase in pressure causes mechanical distension followed by downregulation of the diameter due to the smooth muscle cells within a minute.

Research description

In this project you will:

1. Make and implement models of diameter regulation in vascular networks. The current single-segment model is implemented in Matlab. Using this environment, you will step by step increase the complexity of the network, starting at simple 3-segment networks and working towards more realistic and larger networks
2. Analyze the behavior of such models: how well do they control local flow? What are critical modeling choices?
3. Provide suggestions for further extension of the work

Requirements

We are looking for Bachelor or Master students with an interest in physiological modeling and simulation, including but not limited to students in Biomedical Sciences, Informatics, Bio-informatics, and Physics. We expect you to have some programming skills; experience in Matlab would be handy but is not required. The duration of the internship can be adjusted based on your wishes and curriculum requirements, but is at least 3 months full time. Start date is flexible.

Learning outcome

You will gain knowledge on quantitative analysis of complex systems and of the cardiovascular system. You will have the opportunity to develop your programming skills. You will learn to act in an interdisciplinary and international research group, acquiring competences which include collaboration, scientific writing, and scientific presentation.

References

1. Wesselman JP, VanBavel E, Pfaffendorf M, Spaan JA (1996) Voltage-operated calcium channels are essential for the myogenic responsiveness of cannulated rat mesenteric small arteries. J Vasc Res 33: 32-41.
2. Sorop O, Spaan JA, Sweeney TE, VanBavel E (2003) Effect of steady versus oscillating flow on porcine coronary arterioles: involvement of NO and superoxide anion. Circ Res 92: 1344-1351.
3. van den Akker J, Schoorl MJ, Bakker EN, Vanbavel E (2010) Small artery remodeling: current concepts and questions. J Vasc Res 47: 183-202.
4. Spaan JA, ter Wee R, van Teeffelen JW, Streekstra G, Siebes M, et al. (2005) Visualisation of intramural coronary vasculature by an imaging cryomicrotome suggests compartmentalisation of myocardial perfusion areas. Med Biol Eng Comput 43: 431-435.

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