BFI

Blood Flow Imaging Group

by Dmitry Postnov

Introducing the BFI group

The Blood Flow Imaging group was established at CFIN on September 1st 2021, with the financial support of the Lundbeck Foundation Fellowship awarded to Dmitry Postnov (PI). As the BFI group, we focus on developing non-invasive blood flow and oxygenation imaging technologies and applying them to unravel the microvascular mysteries in health and disease. Structural and functional abnormalities in small vessels and microcirculation play a critical role in various conditions, including different forms of dementia, hypertension and diabetes. By understanding the cause of such abnormalities and developing new ways to monitor them, we aim to improve diagnostics and treatment of related diseases. The BFI group is interdisciplinary by nature, as our research includes animal and human experiments, engineering, and data analysis and relies on knowledge of physics and physiology. The main tools we utilize are based on light scattering and absorption imaging to provide blood flow and oxygenation information.

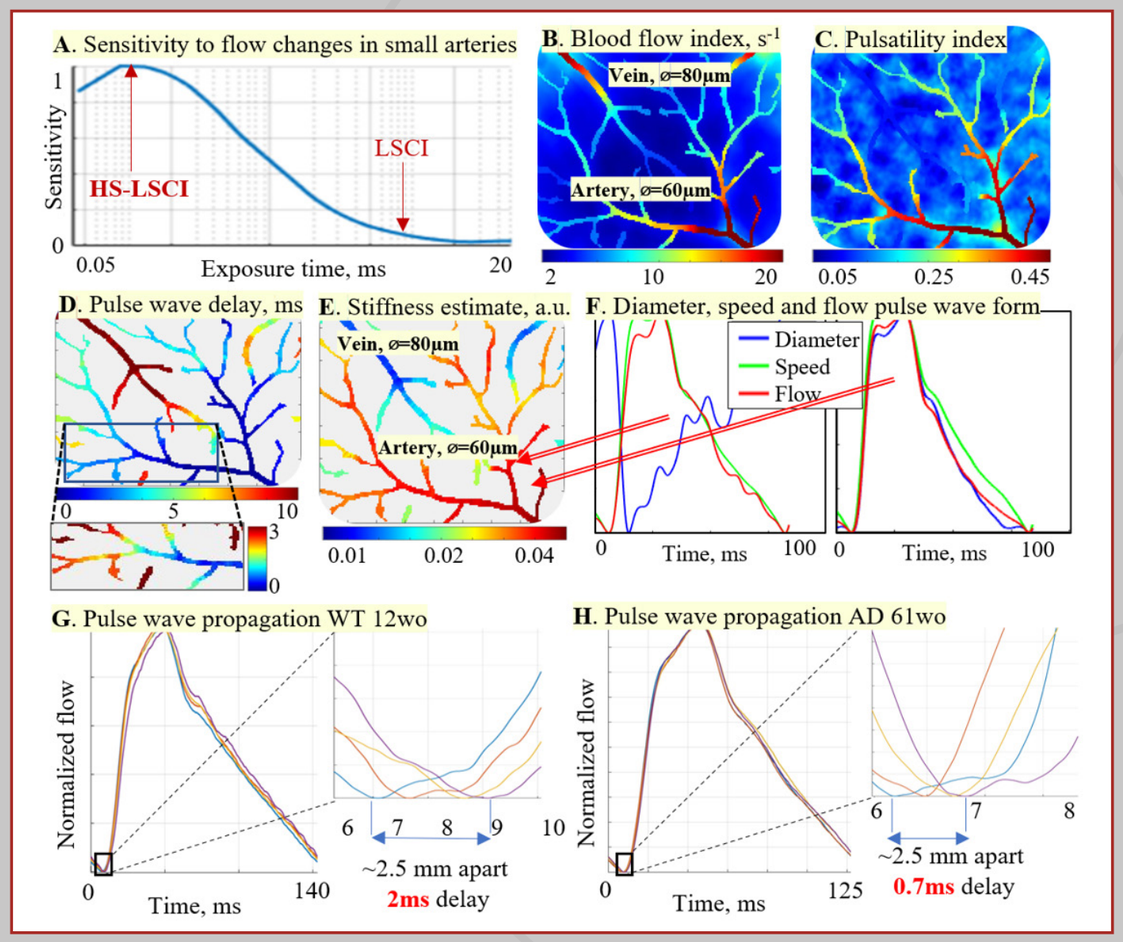


Figure 1
Stiffness characterization with High-Speed Laser Speckle Contrast Imaging. A. HS-LSCI demonstrates sensitivity enhanced by ~15 times (meassured experimentally) compared to conventional LSCI when applied to flow in small arteries. B – quantitative (reverse correlation time) blood flow index map of mouse barrel cortex area. C – Pulsatility index map, clearly showing the difference in pulsatility in arteries, parenchyma and veins. D – Pulse wave delay mapping. E. Corresponding stiffness estimate map. F – fine features of diameter, blood flow and flow speed in the 4th and 3rd branches of middle cerebral arteries. G and H – pulse wave propagation along the 4th branch of the middle cerebral artery in 12 weeks old wild type mouse and 61 weeks old AD mouse. Corresponding PWV values calculated from foot-to-foot pulse wave delay are 1.25 and 3.57 meters per second.

HS-LSCI, microvascular stiffness and cognitive decline

As the key project over 2021-2022, we have developed a new technology called High-Speed Laser Speckle Contrast Imaging (HS-LSCI). It is based on our recent discoveries in the field of dynamic light scattering and speckle dynamics and allows imaging of blood flow at more than 5000 frames per second with high spatial resolution and better signal-to-noise ratio than in conventional laser speckle contrast imaging (see Figure 1). Furthermore, compared to vessel visualization using contrast agents, imaging blood flow allows the detection of flow changes associated with sub-pixel diameter changes and pulsatility measurements in the parenchymal tissue.

The technology development in the BFI lab is always application driven. In the case of HS-LSCI – the physiological target is the assessment of microvascular stiffness, how it changes and what role it plays in cognitive decline. Stiffness reflects vessels' (dis)ability to regulate the blood flow by changing their diameter. The higher stiffness is, the more difficult it becomes for the vessel to dilate or contract in response to a functional activation or pressure change. Increased stiffness of large vessels (e.g., aorta or carotid artery) contributes to cognitive impairment, stroke, and cardiovascular disorders. We hypothesize that the stiffness of small vessels increases in the early stages of the disease (way before it can be detected in large vessels) and plays a critical role in neurovascular coupling and blood-brain barrier impairment. However, due to technical limitations, existing in-vivo tools can only assess stiffness in large vessels, and very little is known about microvascular stiffness and its effects. With HS-LSCI, we can measure stiffness and pulse wave velocity where associated microvascular abnormalities originate and have the most significant role – at the level of small arteries and capillaries. This summer, we completed the validation of the technology by characterizing microvascular stiffness in ageing mice brains and submitted a patent application[1].

The HS-LSCI application is not limited to the rodent brain. Our goal and one of the main aims of the Lundbeck Foundation

FACTS

Group members:

- Dmitry D Postnov
- Alberto Gonzales Olmos
- Mia Viuf Skøtt

Key collaborators:

- Vladimir Matchkov
- Eugenio Gutierrez
- Christian Aalkjær
- Niels-Henrik Buus
- Toke Bek
- David Boas
- Martin Lauritzen
- Changsi Cai
- Osama F Harrazt

Research areas:

- Blood flow imaging
- Image analysis
- Vascular physiology
- Neurovascular coupling
- Dementia
- Hypertension
- Diabetes
- Stroke

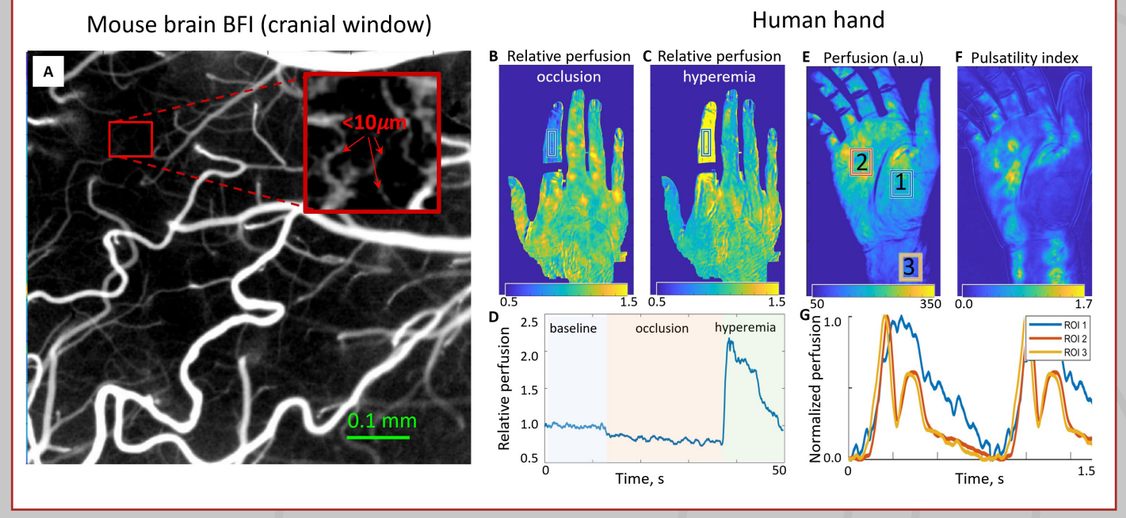


Figure 2
Examples of LSCI recordings in the mouse cortex (A) and human hand (B-G). A – blood flow index mapping in mouse cortex. B,C,D changes in the skin perfusion during occlusion and the following reactive hyperemia. E,F,G – perfusion and pulsailtiy in resting state

Fellowship project is to translate its application to patients with dementia and hypertension by monitoring microvascular abnormalities in their retina and associating them with changes in brain perfusion.

Collaborative projects

We have multiple ongoing projects with colleagues at Aarhus and Copenhagen Universities and our friends from the US. Several projects are related to stroke research, with an exciting one looking into how the pulsatility and resistivity indexes change in stroke in the ipsilateral and contralateral hemispheres. The project is translational – we will combine laser speckle contrast imaging of blood flow in rats with the data collected from patients at AUH. This way, we hope to identify a better way to interpret clinically measured pulsatility and resistivity indexes, improve the quality of post-stroke monitoring, and explain the perfusion changes in the "control" hemisphere.

Another interesting translational application we are working on is the diagnostics of microvascular disease based on human skin perfusion. It is an upcoming collaborative project involving researchers from Bisperbjerg Hospital, Copenhagen and Aarhus Universities. As the BFI group, we will test if non-invasive monitoring of peripheral perfusion and vasoreactivity can replace conventional O-PET diagnostics. For this purpose, we designed a wide-field LSCI system that can be safely applied to image human skin and will look into blood flow changes during reactive hyperemia in patients with microvascular disease and healthy controls (see Figure 2).

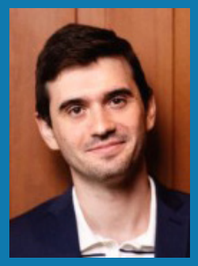
At the BFI group, we are always open to new collaborations – feel free to write to dpostnov@cfin.au.dk if you need help with blood flow imaging, hemodynamic modelling or vascular image/signal analysis.

References

1. Postnov DD, Gonzales Olmos A, "High-Speed Laser Speckle Contrast Imaging". Patent pending, application number EP 22173808. 2022

NEW FACES at CFIN

Introducing the BFI - Blood Flow Imaging Group



Assistant Professor **Dmitry Postnov** joined CFIN as the PI of the Blood Flow Imaging Group and Lundbeck Foundation Fellow in September 2021.
For the past ten years, Dmitry has been developing blood flow imaging technologies and using them to study microvasculature in health and disease. His background is just as interdisciplinary – Dmitry has an MSc in physics, a secondary degree in computer science and a PhD in cardiovascular physiology. Before joining CFIN, he worked as a postdoctoral fellow at Boston and Copenhagen Universities. Various funding bodies supported Dmitry's research proposals and ideas throughout his career – starting with a PhD scholarship from the Faculty of Health of the University of Copenhagen (2013-2016), followed by the Novo Nordisk Postdoctoral research abroad grant (2017-2021) and now with Lundbeck Foundation Fellowship (2021-2026). At CFIN, Dmitry will use his expertise to uncover brain perfusion abnormalities in dementia and associated risk factors.

Alberto Gonzales Olmos joined the BFI group as a PhD student in September 2021.
He is a passionate engineer (BSc Electrical Eng., MSc Biomedical Eng.) with diverse experience and interests in computer science and medical technology. Alberto's primary project as a PhD student and a member of the BFI lab is developing microvascular stiffness imaging technology and assessing the related biomarkers in animal models of hypertension and Alzheimer's disease.

Mia Viuf Skøtt joined the BFI group as a PhD student in October 2022.
She is educated in biology and did her Bachelor's project at CFIN under the supervision of Tobias Wang (Department of Biology - Zoophysiology) and Nina Kerting Iversen. Now she has re-joined CFIN to find out how the microvascular changes in the retina and brain are associated. Her study will focus on correlating perfusion abnormalities in these two organs in patients with hypertension and Alzheimer's disease and respective animal models.