1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title:

Methods of assessing the dynamic properties of human retinal vessels in vivo for the purposes of early diagnosis of systemic diseases.

1.1. Project goals

Project goal is to develop a methodology for quantification of human retinal vessels for diagnostics of systemic diseases in clinical conditions and can be divided into three more specific aims:

- development of optical methods for high spatial and temporal resolution imaging of human retinal vessels in-vivo using scanning laser ophthalmoscopy,
- development of numerical methods for quantification of morphology and dynamics of the vessels imaged by the device,
- use of the designed methodology of vessel quantification to assist medical doctors in the search of biomarkers of systemic civilization diseases such as hypertension or diabetes.

1.2. Outline

Microcirculation is a part of the circulatory system located between the arterial and venous systems. It has many vital functions, including the exchange of nutrients and metabolites between blood and tissues, thermoregulation, protection against significant pressure fluctuations that can lead to diffusion disorders and organ damage, and adjustment of circumferential resistance. Changes in the area of microcirculation occur not only in parallel but may significantly precede the appearance of the first symptoms of cardiovascular disease. For this reason, the assessment of the microcirculation area and the structural and functional changes occurring in it may be particularly important in identifying cardiovascular diseases in the subclinical phase. One of the examples of such structural and functional changes is the process of vascular remodeling, in which vessel wall thickness and lumen diameter change in the course of hypertension or diabetes.
The retina of the eye is the part of the human body where the microcirculation and the morphology and dynamics of individual vessels can be directly observed and quantified in vivo under normal blood pressure conditions. In the Department of Biophotonics and Optical Engineering we have built a high-resolution scanning laser ophthalmoscope (SLO) with an adjustable field of view to observe vessels in the human retina in-vivo and started a collaboration with Gdańsk Medical University that offers access to cohort of patients with various systemic diseases and to medical doctors interested in developing new diagnostic methods.

1.3. Work plan

- Literature review and introduction to ophthalmic imaging methods and techniques with emphasis on the scanning laser ophthalmoscopy and optical coherence tomography as tools to provide information of blood flow in retinal vessels.
- Design and implementation of optimal image acquisition procedures for quantification of retinal vessel morphology and dynamics.

- Design and implementation of image processing techniques to extract and quantify the morphological parameters of retinal vessels, such as lumen diameter, external diameter, vessel wall thickness, wall cross-sectional area, wall-lumen ratio and others. Extension of the methods to follow the evolution of these parameters in time.
- Validation of the retinal vessel quantification methodology in experiments with healthy human subjects in laboratory and in collaborating clinics.
- Verification of the method in the experiments designed to show the changes in vessel morphology and dynamics caused by disease progression or after introduction of treatments.
- Development of candidates for retinal vessel based biomarkers for diagnostics and/or monitoring of systemic diseases.

1.4. Literature *(max. 10 listed, as a suggestion for a PhD candidate)*

1) Park, J.B., Schiffrin, E.L., "Small artery remodeling is the most prevalent (earliest?) form of target organ damage in mild essential hypertension," J Hypertens. 19:921–930 (2001).
2) Mulvany, M.J., Baumbach, G.L., Aalkjaer, C., et al. "Vascular remodeling," Hypertension 28: 505–506 (1996).
3) Renna N.F., de las Heras, N., Miatello, R.M., "Pathophysiology of Vascular Remodeling in Hypertension," Int. J. of Hypertens. Article ID 808353 (2013).

1.5. Required initial knowledge and skills of the PhD candidate

- Background in physics, mathematics, informatics or similar. Knowledge in optical physics and optical imaging will be an advantage.
- Basics in computer programming (preferably Python, Labview, Matlab, C/C++/C#), knowlegde of GPU programming will be an advantage.
- Knowledge of English is mandatory.

1.6. Expected development of the PhD candidate's knowledge and skills

It is expected that the PhD candidate will develop the following main skills during the PhD:

- The capacity to plan, implement and critically analyse novel experimental methodology related to retinal imaging.
- The capacity to create, implement and modify algorithms required in the implementation of quantification of vessel morphology and dynamics.
- The capacity to independently carry out clinical studies using ophthalmic imaging devices, with guidance from the supervisory team.
- The capacity to clearly communicate research ideas and results in English, both in written and oral formats. Particular emphasis will be placed on writing journal papers and delivering conference presentations.