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Final Report for the Nicholas and Elizabeth Slezak Super Center for Cardiac Research and Biomedical Engineering at Tel Aviv University:

A photoacoustic method for simultaneous in-vivo measurement of blood flow and sO2

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Photoacoustic (PA) imaging and spectroscopy is based on measurement of the acoustical waves which are generated due to the absorption of modulated light in a tested medium. PA is widely known for its excellent performance in vascular imaging. The main reason for that is the relatively high absorption of hemoglobin in the visible and near-IR spectral regions. Photoacoustics enables high resolution imaging at depths where most purely optical imaging techniques are not functional due to excessive optical scattering. One very useful attribute of PA imaging is its ability to determine the oxygen saturation level of the blood (sO_2). This is typically implemented by using multispectral PA excitation. During the recent research year we focused on developing a new photoacoustic method for simultaneous measurement of flow and oxygenation. We termed this method "Photoacoustic Thermal Diffusion Flowmetry". Thermal Diffusion Flowmetry (TDF) (also called Heat Clearance Method or Thermal Clearance Method) is a longstanding technique for measuring blood flow or blood perfusion in living tissues. Typically, temperature transients and/or gradients are induced in a volume of interest and the temporal and/or spatial temperature variations which follow are measured and used for calculation of the flow. In our new method the heat deposition which is required for TDF was implemented Photothermally (PT) and the measurement of the induced temperature variations was done by Photoacoustic (PA) thermometry. Both excitation light beams (the PT and the PA) were produced by directly modulated 830nm laser diodes and were conveniently delivered to the volume under test by the same optical fiber. The method was tested experimentally using a blood-filled phantom vessel and the results were compared with a theoretical prediction based on the heat and the photoacoustic equations. The fitting of a simplified lumped thermal model to the experimental data yielded estimated values of the blood velocity at different flow rates.

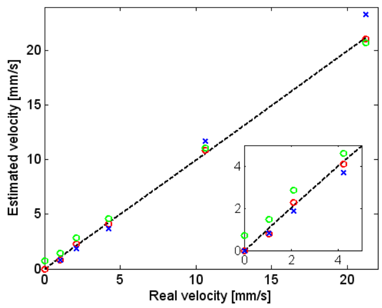

Figure: Measured velocity vs. real velocity: Estimation based on the complete lumped model (red circles). Estimation based on a lumped model which ignores thermal conduction (green circles). Estimation based on only 2 PT modulation frequencies: 1 Hz and 15 Hz (blue x). Dotted black line indicates the 45° line. Inset: zoom-in on the range of low velocities.

By combining additional optical sources at different wavelengths it will be possible to utilize the method for non-invasive simultaneous measurement of blood flow and oxygen saturation using a single fiber probe. The results of this work were published in: *Adi Sheinfeld and Avishay Eyal, "Photoacoustic thermal diffusion flowmetry," Biomed. Opt. Express* ***3****, 800-813 (2012),* and acknowledgment of the funding of the Nicholas and Elizabeth Slezak super center for Cardiac Research and Biomedical Engineering was given.