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World Summit on COPD

March 07, 2022 | Webinar

Measurement of adult human brain responses to breath-holding by multi-distance hyperspectral near- infrared spectroscopy

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Chronic obstructive pulmonary disease (COPD) leads to a complex variety of pathological changes in the human body from systemic level, such as hypertension, anemia, heart failure, and Alzheimer's disease [1-4], to tissue and subcellular levels, such as deterioration of blood vessels and mitochondrial dysfunction [5-7]. Diagnostics of such conditions and control of the therapy outcomes require measurement and imaging tools capable of objective quantitative assessment of the degrees of pathologies at all levels. Near-infrared spectroscopy (NIRS) [8] is a novel non-invasive quantitative imaging modality, which currently is being tested in many medical applications including COPD. Light of near-infrared wavelengths (700 nm - 900 nm) can penetrate tissues to the depth of 2 – 3 cm without harmful effects on cells. NIRS can non-invasively measure local concentrations of tissue chromophores, such as oxy- and deoxy- hemoglobin, water, fat, melanin, and cytochrome C oxidase (CytOx). This allows for using NIRS for non-invasive analyses of blood oxygenation, tissue blood concentration, and oxygen consumption. Target tissues include all organs accessible from the surface of the body through the superficial tissues, in particular the cerebral cortex. While NIRS methodology for measuring blood parameters and oxygen consumption in muscles was well established in 1990s, measurements of CytOx and all types of cerebral measurements in adults still remain hot research topics. CytOx is an enzyme participating in the respiratory electron transport chain in mitochondria of cells [6]. Since CytOx absorbs near-infrared light, it is an important intracellular marker of the oxygen metabolism. However, the problem is that the tissue concentration of CytOx is much lower than the concentration of hemoglobin. Challenges of cerebral NIRS in adult humans are caused by the strong light absorption in the scalp and by the strong scattering in the skull and meninges. For these reasons, reliable non- invasive measurements of CytOx in the brain and muscles, and of CytOx and hemodynamics in cerebral cortex by NIRS became possible only recently, after the introduction of novel highly sensitive broadband detectors of light and with the development of advanced signal acquisition techniques and signal processing algorithms. Our group contributed to the development of the hyperspectral NIRS (hNIRS) of the brain, which is capable of measuring cerebral hemoglobin and CytOx [9]. In COPD the interest to NIRS has been increasing since 2016, but is limited mostly to measurements of muscle oxidative capacity, muscle blood oxygenation, and vascular endothelial damage in COPD patients [7]. However, the potential of NIRS for COPD applications is significantly wider, as NIRS can be also used for the assessments of cerebral and mitochondrial pathologies (due to its capacity to measure CytOx). In particular, some authors have found increased concentration and pathological activity of CytOX in the muscles of COPD patients [5,6]. So far the analysis of the muscle CytOx has been performed ex vivo using muscle biopsy, while hNIRS allows for the non-invasive in-vivo measurements of CytOx in muscles. Also hNIRS has a potential to measure both vascular and mitochondrial pathologies caused by chronic hypoxia in the brain of COPD patients, which recently were linked to increased risk of stroke [2], cognitive decline [3], and Alzheimer's disease [4].

Biography

Vladislav Toronov PhD is an Associate Professor of Medical Physics, Ryerson University, and a research member of iBEST Institute, Toronto, Canada. He received his PhD in Physics from Saratov State University, Russia. Before accepting his current faculty position, he was a senior research scientist in Biomedical Physics in the University of Illinois at Urbana-Champaign. His research interests include biomedical applications of Optics and brain imaging. His research papers have been cited by more than 2,800 authors.