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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].

In my presentation I will review the current state of the art of NIRS, all aspects of brain and muscle NIRS, our current studies on cerebral hNIRS, and discuss current and potential future uses of NIRS in COPD.

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.

About the University

The Ryerson Institute of Technology was established in 1948 and gained official university status in 1993. Research funding and publications at Ryerson have doubled in the past five years. Ryerson's interdisciplinary approach to research represents the collaboration of over 125 centers, institutes and labs and over 190 local, national and global funding partners. At Ryerson University's Department of Physics, our research spans two broad areas: medical physics and complex systems. Our various labs explore both theoretical and applied topics in physics and medical physics. Most of our faculty members and researchers have research facilities at nearby hospitals and research institutes, and collaborate closely with clinicians and researchers. Many also work with industrial collaborators to translate clinically-focused research to market, with real-world impact on medicine. The Institute for Biomedical Engineering, Science and Technology (iBEST) is a partnership between Ryerson University and St. Michael's Hospital that brings together Ryerson's engineering and science strengths with St. Michael's biomedical research and clinical expertise to translate research concepts into testable healthcare solutions.

References

1. Hawkins, N. M., Petrie, M. C., Jhund, P. S., Chalmers, G. W., Dunn, F. G., & McMurray, J. J. (2009). Heart failure and chronic obstructive pulmonary disease: diagnostic pitfalls and epidemiology. European journal of heart failure, 11(2),130–139. https://doi.org/10.1093/eurjhf/hfn013
2. Lahousse, L., Tiemeier, H., Ikram, M. A., & Brusselle, G. G. (2015). Chronic obstructive pulmonary disease and cerebrovascular disease: a comprehensive review. Respiratory medicine, 109(11), 1371-1380.
3. De Carolis, A., Giubilei, F., Caselli, G., Casolla, B., Cavallari, M., Vanacore, N., ... & Orzi, F. (2011). Chronic obstructive pulmonary disease is associated with altered neuropsychological performance in young adults. Dementia and Geriatric Cognitive Disorders Extra, 1(1), 402-408.
4. Zhang, F., Niu, L., Li, S., & Le, W. (2018). Pathological impacts of chronic hypoxia on Alzheimer's disease. ACS Chemical Neuroscience, 10(2), 902-909.
5. Puente-Maestu, L., Lázaro, A., & Humanes, B. (2013). Metabolic derangements in COPD muscle dysfunction. Journal of applied physiology, 114(9), 1282-1290.
6. Lerner, C. A., Sundar, I. K., & Rahman, I. (2016). Mitochondrial redox system, dynamics, and dysfunction in lung inflammaging and COPD. The international journal of biochemistry & cell biology, 81, 294-306.
7. Theodorakopoulou, M. P., Bakaloudi, D. R., Dipla, K., Zafeiridis, A., & Boutou, A. K. (2021). Vascular endothelial damage in COPD: current functional assessment methods and future perspectives. Expert review of respiratory medicine, 15(9), 1121-1133.
8. Siesler, H. W., Kawata, S., Heise, H. M., & Ozaki, Y. (Eds.). (2008). Near-infrared spectroscopy: principles, instruments, applications. John Wiley & Sons.
9. Guerouah, Z., Lin, S., & Toronov, V. (2022). Measurement of Adult Human Brain Responses to Breath-Holding by Multi-Distance Hyperspectral Near-Infrared Spectroscopy. Applied Sciences, 12(1), 371.