Development of Optical Wearable Devices for Non-invasive Monitoring of Tissue Oxygenation and Carbon Dioxide

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In this presentation, I will describe in detail my postdoctoral work developing optical transcutaneous gas monitoring wearables, and how we built and validated this technology with the combined expertise of physicists, chemists and engineers, physicians, etc.

Continuously monitoring transcutaneous O_2 and CO_2 partial pressure ($tcpO_2$ or $tcpCO_2$) can be of crucial importance in the diagnosing and treating respiratory and cardiac diseases. Despite significant progress in the development of sensors, commercially available devices remain bulky and present limited application, and their implementation as portable or wearable devices for real-time monitoring remains under-explored.

We present the first pilot human studies using our oxygen-sensing technology based on the oxygen quenching of phosphorescence of our in-house developed metalloporphyrins. In these measurements, we were able to successfully detect local changes in tissue oxygenation transcutaneously by restricting blood flow to the subjects' forearm or calf with the application of a pressure cuff. We have also been able to detect changes in $tcpO_2$ arising from systemic changes in blood flow due to strenuous exercise as well as due to increased blood flow to skin due to local heating. We explore numerical models to extract tissue oxygenation and oxygen consumption rate on the skin surface. The clinical results show that our devices are capable of producing reliable $tcpO_2$ readings under changing conditions of temperature, motion, etc. without the need for large devices.

We also report on the creation of a wearable prototype devices for transcutaneous CO_2 monitoring using a similar approach to oxygen. The sensing mechanism relies on a ratiometric approach with dual wavelength excitation of a CO_2-sensing fluorescent HPTS dye (CO_2 sensing) embedded into hydrophobic polymer matrices. The films' signals are highly sensitive to changes in O_2/CO_2 in the physiological range.