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Biophotonic telemedicine for disease diagnosis and monitoring during pandemics: Overcoming COVID-19 and shaping the future of healthcare

In order to contain the progression of airborne droplet, contact transmissible diseases such as the coronavirus disease 2019 (COVID-19), the World Health Organization (WHO) released infection prevention and control (IPC) strategies [1] to be followed globally. The clinical management of pandemic relies on enabling telemedicine associated to disease diagnosis and monitoring. This letter aims to highlight the opportunities of applying optical/biophotonic technologies for disease diagnosis and monitoring in pandemic settings as well as to foster the adaptation of these technologies to contain the coronavirus spread. Particular focus is given to practical implementation of telemedicine applications including the COVID-19 detection, real-time responses on the individual vital signs (VS), and monitoring the status of patient at isolation rooms.

As the incidence of COVID-19 increases exponentially worldwide, the demand for physicians, hospital beds, personal protective equipment, and isolation rooms to control the pandemic has overwhelmed the healthcare system [2,3]. In order to ensure the safety of healthcare professionals and comply with the WHO IPC strategies, telemedicine has become one of the main clinical practices. Telemedicine is only efficient when patient status is continuously monitored and accurate reports are sent to clinicians upon degradation of patients' condition. Reports should be timely in order to allow physicians to manage their patients without information overload, and to increase the technology adoption by clinicians. Reliably identifying the patient symptoms in a timely fashion allows the early detection of the disease, which improves the treatment outcome and increase survival rates. COVID-19 early diagnosis are based on symptoms such as fever, pneumonia, acute respiratory distress syndrome (ARDS) [4], which are associated with patient VS including temperature, blood oxygenation and heart rate. Standard of care to monitor patient VS is currently performed by optical and biophotonic technology, which allows non-invasive, real-time, and label-free analysis of biological tissues.

Optical techniques have been widely used to monitor patient VS. Monitored VS include blood oxygenation, heart rate and, in selected facilities, blood pressure by using pulse oximeters as well as temperature by using infrared sensors. In addition, patient respiratory rate can be continuously measured by sensors based on Bragg grating and fiber bending to monitor [5] during magnetic resonance imaging scans. The maturity of optical-telemedicine technology for accurate reporting of patient VS as well as its integration into portable/wearable devices makes this technology attractive to overcome the pandemic and global diseases as a whole. Increasing the availability of this technology in the healthcare system can improve the clinical management of complications deriving from COVID-19. In a short-term, this increase may be done by studying the feasibility of the existing tools for COVID-19 diagnosis. One possibility is using available smartphone and smartwatch applications for monitoring individual VS, which are user-friendly and can be adapted for personal use out of the medical institutions. In this case, optimizing the VS measurement protocol for early COVID-19 identification is required to reliably determine possible COVID-19 candidates to be investigated further. The optimization could be performed by analyzing large data volumes generated from smart devices. Identification of other conditions can also be performed by combining optics with technologies already integrated in smart devices such as electrocardiogram (EKG), which can detect atrial fibrillation. The same steps are needed for upcoming technology, which can be tested in a smaller scale before translation to large production volumes. This translation is important to decrease costs and increase the technology adoption, especially considering that less people can afford smart devices for personal use during the pandemic.

Conventional technology is based on visible wavelength (VISW) spectrometry and imaging for determination blood oxygenation and heart rate. These parameters may be related to pneumonia and ARDS, and, thus, may be associated to the outcome of oxygen therapy or mechanical ventilation. On the other hand, upcoming technology for VS monitoring may involve adaptations of portable or wearable devices for quantification of tissue water and lipid content (by wavelength selection on excitation and collection) as well as selection of the tissue probed depth (by time-gating detected photons or optimizing the probe source-to-detector distance). In order to successfully adapt devices for medical use and create user-friendly applications, both manufacturers and consumers need to be involved in the early stages of the design development. One relevant aspect usually neglected by manufacturers is the consumers' unwillingness to carry more devices in addition to a smartphone and a smartwatch, regardless of the instrumentation portability. User-friendly instrumentation may consist of VISW and near-infrared (NIR) microspectrometers, which can be coupled or integrated into smartphones. NIR spectroscopy may identify pneumonia cases by monitoring the lung water content, since these cases are characterized by excess of pus or fluid in the alveoli. The water accumulation can be localized by using diffuse optical tomography or spatial frequency-domain imaging. Another upcoming technology is gas in scattering media absorption spectroscopy (GASMAS), which can determine the oxygen gas concentration inside the lungs and provide guidance on the choice of treatment modalities. The proposed methods can overcome the screening limitations of current techniques to identify respiratory infections such as the ionizing radiation exposure of computed tomography.

In order to overcome the COVID-19 pandemic, I would like to encourage researchers, the photonics industry and medical institutions to focus on the development of user-friendly technology capable of generating telemedicine patient reports complying with health Insurance regulations and associated business agreements of their countries/regions. In several countries, although the guidelines for the use of telehealth remote communications became more flexible during the pandemic, complying with regulations means that patients need to be

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notified about privacy risks of any used technology and video communications should be avoided. Then, establishing reliable telemedicine protocols and technology should take into consideration aspects of existing regulations and consumer adoption. Even though difficult times require thoughtful measures to contain the coronavirus spreading, advancements in optics and biophotonics will remain useful for the healthcare system as a whole. As the pandemic reinforced the concept of global health, biophotonic telemedicine can shape the future of healthcare.

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Ethical approval

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Declaration of Competing Interest

No conflicts of interest to declare.

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