Smart Sensing for COVID-19 Pandemic

Charles Oluwaseun Adetunji, Olugbemi Tope Olaniyan, Olorunsola Adeyomoye, Ayobami Dare, Mayowa J. Adeniyi, Enoch Alex, Maksim Rebezov, Olga Isabekova, and Mohammad Ali Shariati

1 Introduction

COVID-19 is a severe respiratory disease of public health concern with detrimental effects on human health [1, 2]. Moreover, owing to its rapid and widespread

C. O. Adetunji (✉)
Applied Microbiology, Biotechnology and Nanotechnology Laboratory, Department of Microbiology, Edo University Iyamho, Auchi, Edo State, Nigeria
e-mail: adetunji.charles@edouniversity.edu.ng

O. T. Olaniyan
Laboratory for Reproductive Biology and Developmental Programming, Department of Physiology, Edo University Iyamho, Iyamho, Nigeria

O. Adeyomoye
Department of Physiology, University of Medical Sciences, Ondo City, Nigeria

A. Dare
Department of Physiology, School of Laboratory Medicine and Medical Sciences, College of Health Sciences, Westville Campus, University of KwaZulu-Natal, Durban, South Africa

M. J. Adeniyi
Department of Physiology, Edo State University Uzairue, Iyamho, Edo State, Nigeria

E. Alex
Department of Human Physiology, Ahmadu Bello University Zaria, Kaduna State, Nigeria

M. Rebezov
Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia

K.G. Razumovsky Moscow State University of Technologies and Management (the First Cossack University), Moscow, Russia

O. Isabekova · M. A. Shariati
K.G. Razumovsky Moscow State University of Technologies and Management (the First Cossack University), Moscow, Russia

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transmission, smart sensing has been considered as global strategies that could be applied in reducing the rate of transmission at the early stage. This has been shown to be very important technique that could be utilized in prevention of this pandemic situation [3].

It has been discovered that different healthcare system across different countries have incorporated massive testing devices, sensors and biosensors that help in the identification of COVID-19 on infected patients, as well as provision of potent therapeutic intervention for these patients. Also, several countries have adopted other protocols which entail lockdown regulations most especially in endemic areas that could help in reducing the spread of infection during COVID-19 pandemic [4]. Therefore, to sustain the healthcare system and effectively implement the restriction protocol across the countries, potent approaches to shape the society is highly important. Typical examples of these approaches entail the application of smart technologies in different sectors including the healthcare sector [5]. This paradigm shift toward technology-based approach has increased the urge for novel techniques, thereby increasing the significance of technologies in the health sector [6]. Smart technologies include drones, telehealth, robotics, and artificial intelligence which are used during COVID-19 pandemic to disinfection, promote consultation between patients and healthcare providers, enhance tracking and contact tracing of infected individuals, deliver medical equipment, and survey and screen people for early diagnosis of SARs-CoV-2 infection [7]. The synergistic contributions from several health sectors, incorporation of technology-based approach, and adequate government regulation have provided a potent strategy to alleviate COVID-19 pandemic. Undoubtedly, the significant impact of technology-based approach in curtailing COVID-19 infection requires proper understanding. This will enable scientist to decipher the mode of operation of these innovative techniques during COVID-19 pandemic. The article highlights the various smart technologies and their potential application to curtail COVID-19 pandemic.

Therefore, this chapter intends to provide detailed information on the utilization of smart technology in reducing the spread of COVID-19 diseases. Figure 1 shows the various applications of biosensors in the detection of COVID-19 diseases.

2 Application of Sensors and Biosensors for Monitoring and Detection of COVID-19

It has been discovered that there is a need to innovate a diagnostic test that could be applied in rapid recognition of affected people with outbreak of the coronavirus disease (COVID-19) in order to prevent the spreading of this virus. Mojsoska et al. [8] stated the role of a proof-of-concept label-free electrochemical immunoassay for swift identification of SARS-CoV-2 virus through the spike surface protein. The assay entails a grapheme that works with electrode functionalized with anti-spike antibodies. The immunosensor works on the principles which entails identification

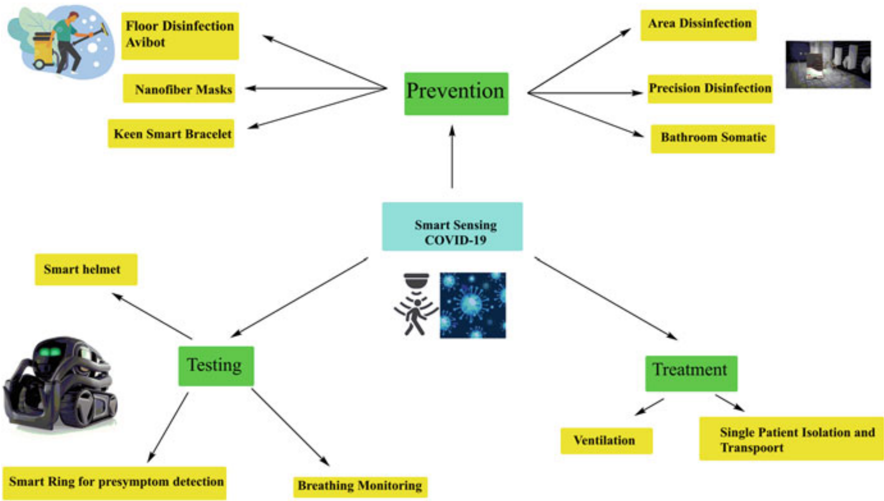

Fig. 1 Shows the various applications of biosensors in the detection of COVID-19 diseases

of signal perturbation derived from ferri/ferrocyanide determination after joining with the antigen during 45 min of incubation with a sample. The total alteration in the $[Fe(CN)_6]^{3-/4-}$ current upon enhancing the level of antigen concentrations on the immunosensor surface was applied in evaluating the identification range of the spike protein. The sensor portent the capability to identify a specific signal above 260 nM (20 µg/mL) of subunit 1 of recombinant spike protein. Moreover, it could identify SARS-CoV-2 at a concentration of 5.5×10^5 PFU/mL, which falls within physiologically applicable concentration values. It was discovered that novel immunosensor has a meaningfully faster investigation time than the standard quantitative polymerase chain reaction (qPCR) coupled with a portable device that can enable on-site evaluation of infection.

Quick and timely identification of COVID-19 diseases has been identified as a measure that could be applied in the prevention of this pandemic outbreak. It has become mandatory to enhance healthcare quality in airports, markets, public places, schools so as to generate necessary insight into the technological environment and assist researchers recognize the selections and gaps existing in this field. In view of this, Taha et al. [9] wrote a comprehensive report on the application of biosensors that works based on the application of laser detection technology.

The authors provide three useful points such as means of assessment of hazard of pandemic COVID-19 transmission styles in comparison with Middle East Respiratory Syndrome (MERS) so as to establish the main factor responsible for the spreading of the virus, a life-threatening evaluation that can be applied in identification of coronavirus disease 2019 (COVID-19) that depends on artificial intelligence through *chest x-ray* (CXR) images, computerized tomography (CT) scans, and types of biosensors.

Hussein et al. [10] pointed out five different techniques which entails micro-neutralization evaluation and cell-culture recognition, genetic screening through Real-time polymerase chain reaction (RT-PCR) coupled which shows the gold standard for virus identification most especially in the nasopharyngeal swabs. Moreover, it was stated that immunoassays could be developed either by screening or antigen identification of the whole virus, available in the blood, sera, and the whole virus. Also, proteomic mass-spectrometry (MS)-based technique was identified for the evaluation of the swab samples. Interestingly, virus-biosensing devices have been developed, while eye-based technologies and electrochemical immunosensors could also be used for the identification of virus present in swab. It was also stated that lateral flow point-of-care immunoassays are based on swab-based techniques for the detection of virus in the blood samples. They have merit which includes their portability for on-site evaluation in airports and hotspots, virtually without any sample treatment. Finally, virus-biosensing devices were efficiently designed. Both electrochemical immunosensors and eye-based technologies have been described, showing detection times lower than 10 min after swab introduction. Alternative to swab-based techniques, lateral flow point-of-care immunoassays are already commercially available for the analysis of blood samples. Such biosensing devices hold the advantage of being portable for on-site testing in hospitals, airports, and hotspots, virtually without complicated lab precautions or any sample treatment.

It has been discovered that due to the lack of prophylactic measure for effective management of viral infection, quick identification, as well as their quarantining of asymptomatic infected individuals most especially during this pandemic situation is very difficult. It has been discovered that the current techniques are time consuming and very expensive. Therefore, there is a need to search for more sustainable solutions that could be applied for quick identification of this virus. Vadlamani et al. [11] stated the application of a more cost-effective, and sensitive, cobalt-functionalized TiO_2 nanotubes (Co-TNTs)-based electrochemical sensor that could be applied for rapid identification of the spike (receptor binding domain (RBD)) available on the surface of the virus. The authors applied a cost-effective and simple one-step electrochemical anodization route for the fabrication of TNTs, together with wetting techniques for cobalt functionalization of the TNTs platform, coupled with a potentiostat for data collection. The sensor portends the capacity to identify the S-RBD protein of SARS-CoV-2 even when available in a lower concentration which varies from 14 to 1400 nM (nano molar). The authors also demonstrated a linear rejoinder in the identification of viral protein in a lot of varying concentrations. Therefore, the application of Co-TNT sensor has been discovered to be more efficient in the identification of SARS-CoV-2 S-RBD protein within 30 s, which shows that it can be utilized for development of a point-of-care diagnostics for quick identification of SARS-CoV-2 in saliva samples and nasal secretions.

Mavrikou et al. [12] stated the proof-of-concept development of a biosensor that could be applied in the identification of spike protein present on the surface of the virus. The biosensor works on the principle of membrane-engineered mammalian cells having the human chimeric spike S1 antibody. Their study indicated that the joining of the protein to the membrane-bound antibodies led to discriminatory and considerable alteration in the cellular bioelectric features determined through the help of Bioelectric Recognition Assay. The novel biosensor could detect a semi-linear range of response between 10 fg and 1 μg/mL and a detection limit of 1 fg/mL, while there was no cross-reactivity against the SARS-CoV-2 nucleocapsid protein. Moreover, the biosensor was constructed as a ready-to-use platform, with a portable read-out device that works through a tablet or a smartphone. Their study shows that this novel biosensor could be utilized for mass screening of SARS-CoV-2 surface antigens without going through the process of sample processing. This indicated that this biosensor could be available as a sustainable technique that could be applied for rapid identification and monitoring of this global coronavirus.

Khan et al. [13] reported that the current COVID-19 pandemic can be reduced by adopting the use of smart technology, thus the implementation of these novel innovations will ensure therapeutic advantage together with vaccine development. The authors pointed out that in the implementation of smart technology for the mitigation of global COVID-19 pandemic, specific attention must be given to the utilization of drone, artificial intelligence, robotics, 3D printing, optical sensing, and sensor technology and mask technology in healthcare services through disinfection process, medical assistance, surveillance, prediction of infection diseases, evaluation, data analysis and computing, diagnostics, and controlled monitoring of infected patients.

Erdem et al. [14] demonstrated that COVID-19 has caused a serious of devastating effects on global health system, which needs rapid and aggressive solutions to quickly curtail the spread. The authors noted that effective clinical management and implement strategies through prompt diagnostic techniques are a mainstay. Many of the diagnostic techniques for the screening of this disease include real-time reverse transcriptase (RT)-PCR test, serological assays which are very slow, expensive, and require skilled personnel resulting in greater impediments especially in the low-resource settings. Today, sensor systems provide huge opportunity particularly in the clinical diagnostics settings as complementary options or alternative to the present diagnostic approaches in point-of-care settings, time-effective, and economic perspective way. Sensor technology accommodate the utilization of smart materials like photosensitive materials, nanomaterials, electrically sensitive materials, wearable tools with tremendous analytical performances and physiochemical properties such as linear dynamic range, specificity, and sensitivity for COVID-19 diagnosis.

Gupta et al. [15] showed that in the past few years, rapid development has been seen in the adoption of Internet of Things for healthcare support through different connection with networking, sensors, communication technology, actuators, smart cyberphysical systems, and artificial intelligence globally. The authors noted that the implementation of Internet of Things to mitigate the spread of COVID-19 is paramount. Hence, smart connected technologies and Internet of Things which combine data-driven applications and algorithms are crucial to the continuous monitoring, prevention, evaluation, mitigation, analysis, prediction, and diagnosis of patients and future outbreaks. Recently, different smart technologies like smart home, E-Health, smart transportation, supply chain management, and smart communities have been implemented through cloud-enabled Internet of Things and Amazon Web Services as novel strategy to combat COVID-19.

Damin et al. [16] reported that reverse transcription-quantitative polymerase chain reaction with other specificity and sensitivity analytical techniques have been utilized for the diagnosis of COVID-19. The authors showed that these techniques are less sensitive particularly in asymptomatic individuals with lot of time-wasting efforts. Hence, the introduction of microarray-based assay which is a solid-phase hybridization involving fluorescently labeled amplicons with reverse transcription and RNA extraction. This technique is very sensitive due to the optical-physical properties of the silicon substrate to the viral genes.

3 Application of Drone Technology-Driven Technology and Robotics in Supporting Disinfection Process, Surveillance, and Health System

COVID-19 is a transmissible disease that has claimed responsibility for the death of over 500,000 people worldwide since its onset. The transmissibility of coronavirus necessitates introduction of technology-aided measures to curb the spread of the diseases. Among the technology-aided measures are drone and robotics.

4 Application of Drone-Driven Technology in Supporting Disinfectant Process, Surveillance, and Health System

Drones (Unmanned Aerial Vehicles) are aircrafts that are devoid of pilot. The first unmanned aircraft surfaced during the First World War, but earlier, unmanned aerovehicle known as balloon carrier had been utilized in fighting war in 1849. Drones with different potential benefits as far COVID-19 prevention is concerned have been developed. For instance, drone-based healthcare services for patients with chronic ailments useful in data collection, medication, and healthcare were developed by Kim et al. [17]. Drone-based rescuers and disasters scenario platform created by Camara et al. [18] are useful in monitoring and data collection. Another system for medical services which was useful in monitoring, data collection, medication, and healthcare was created by Graboyes and Skorup [19]. With respect to services such as medication and healthcare, a drone-based system in medical drug supply has been developed [20]. Sethuraman et al. [21] developed a drone-based healthcare platform useful in monitoring and healthcare. Kumar et al. [22] developed a drone-based smart healthcare platform with artificial intelligence which among others may be useful in monitoring of COVID-19, social distancing, data analysis, and statistics.

5 Application in Data Collection

There are many potential drone-based platforms for data collection and statistics. Typical examples of this is found in the drone -based healthcare services which is applicable to patients that are suffering from chronic disease that could help in data collection as described by Kim et al. [17]. Drone-based platform created by Camara et al. [18] was useful in monitoring and data collection. Likewise, the one developed by Graboyes and Skorup [19] is useful in data collection.

6 Application in Aerial Disinfection

Drones have been extensively used in agriculture for spraying. These drones are also applicable in spraying the environment in order to rid the environment of microorganisms [23]. Achieving optimum disinfection is vital for minimizing active or passive COVID-19 transmission. This is much more required in view of the report emanating from New England Journal of Medicine that claims that coronavirus can survive for about 3 h, 4 h, 24 h, and 3 days in the air, copper, cardboard, and steel, respectively [24]. In developing countries like Nigeria with ebbed technology, disinfections were largely achieved through the use of manpower (www.premiumtimesng.com/news/top-news) exposing more lives to COVID-19 risks.

7 Application in Transportation of Medical Materials

Drones have been used in the transport of fragile medical items and pharmaceutical agents. With drones, medical kits and items were delivered to locations and this has contributed to curtaining the spread of the virus. The use of drones for the delivery of medical items occurred in countries like India, China, Chile, Estonia, Canada, Australia, United States, and many more [22].

8 Policy Monitoring and Surveillance

One of the World Health Organization strategies for the control of COVID-19 spread is social distancing. Drones are being used to monitor citizens' compliance to social distancing regulation, crowd tracking, and remote measurements [23].

9 Dissemination of Information During COVID-19

The application of telecommunication was applied for effective dissemination of information to the people in remote locations where communication means are not available. The application of several communication gadgets were deployed for successful dissemination of information majorly on how to mitigate against COVID-19 diseases, application of face mask, constant cleaning of hoods, social distancing, and application of alcohol-based sanitizers. Most people in the rural area in most developing county get access to important information through the help of their telephone and other telecommunication gadgets.

10 Application of Smart Technology in Medical Assistance, Forecasting Infection Threats, Investigating Diagnosis

Robotics are programmable machines that could be applied to perform numerous tasks in different areas in the health sector. The integration of machine learning algorithms and artificial intelligence play major roles most especially in the medical services.

11 Application in the Diagnosis and Rehabilitation

Before the outbreak of COVID-19 in 2019, tele-robots, a mechanism that involves the use of wireless communication network to control robot from a distance, have been used in clinics and hospitals for diagnosis, management, and rehabilitation [25].

12 Collection of COVID-19 Sample

Collaborative robotics, a technology that is operative in proximity with human being, shows promising roles especially with the development of a swab-collecting robot [26]. This robotics is capable of not only collecting specimen from the throats but also submitting it in a sample box [27].

13 Sanitation, Safety, and Management of COVID-19 Situation

It has been documented that it is possible to disinfect public places during COVID-19 era with the help of autonomous robotics. Robotics are also capable of interacting with patients without human interventions, recording health information, and data. These robotics are also capable of giving medical treatment and supplying personal protective equipment and food [28].

14 Application of Robotics in Protecting People During Pandemic Period

The application of robots was shown to be more effective in protecting people from COVID-19 infection. In the COVID-19 pandemic, social robots are used for social interaction and guiding peoples in the hospital. This was also used in fumigation of the environment [29].

15 Measurement of Vital Signs

The application of wearable robotics was normally placed on the body of numerous people in order to measure their body vital signs. Mohammed et al. [30] proposed smart helmet for adequate measurement of body temperature and facial recognition. This was established to be more effective for adequate recording, monitoring, and quick detection of COVID-19 diseases on patients most especially in most crowded areas.

16 Conclusion and Future Directions

This chapter has provided detailed information on the applications of smart sensing as well as biosensors and sensors during COVID-19 pandemic. The application of biosensors and different sensors was established as a major benchmark that played a crucial role in ravaging prevalence of COVID-19 pandemic which actually play a significant role in the prevention of this pandemic disease. Moreover, the application of drones, telehealth, robotics, and artificial intelligence used during COVID-19 pandemic for disinfection, promote consultation between patients and healthcare providers as well as their role in the tracking and contact tracing of infected individuals were highlighted, deliver medical equipment, survey, and screen people for early diagnosis of SARs-CoV-2 infection were highlighted during this study. Also it has been established that the application of technology-driven approaches could play a significant role in promoting social distancing measures, predict possible infections, and optimize the delivery of essential services and resources in a swift and efficient manner. However, large-scale implementation of smart sensing in many societies is usually confronted with numerous difficulties like government regulation and policies, security, and confidentiality, which need to be properly addressed to promote acceptability of this innovative concept. Also, incorporation of smart sensing will facilitate collaborative research that cuts across various disciplines with the development of appropriate technologies to prevent subsequent outbreak. Also, the application of technology-driven approaches with little or no human interference in smart sensing could promote the implementation of preventative strategies that controls the transmission of infection in the society.

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