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Lessons learned from the COVID-19 pandemic: emphasizing the emerging role and perspectives from artificial intelligence, mobile health, and digital laboratory medicine

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ABSTRACT

SARS-CoV-2, the new coronavirus causing COVID-19, is one of the most contagious disease of past decades. COVID-19 is different only in that everyone is encountering it for the first time during this pandemic. The world has gone from complete ignorance to a blitz of details in a matter of months. The foremost challenge that the scientific community faces is to understand the growth and transmission capability of the virus. As the world grapples with the global pandemic, people are spending more time than ever before living and working in the digital milieu,

and the adoption of Artificial Intelligence (AI) is propelled to an unprecedented level especially as AI has already proven to play an important role in counteracting COVID-19. AI and Data Science are rapidly becoming important tools in clinical research, precision medicine, biomedical discovery and medical diagnostics. Machine learning (ML) and their subsets, such as deep learning, are also referred to as cognitive computing due to their foundational basis and relationship to cognition. To date, AI based techniques are helping epidemiologists in projecting the spread of virus, contact tracing, early detection, monitoring, social distancing, compiling data and training of healthcare workers. Beside AI, the use of telemedicine, mobile health or mHealth and the Internet of Things (IOT) is also emerging. These techniques have proven to be powerful tools in fighting against the pandemic because they provide strong support in pandemic prevention and control. The present study highlights applications and evaluations of these technologies, practices, and health delivery services as well as regulatory and ethical challenges regarding AI/ML-based medical products.

1. INTRODUCTION

The first report of a respiratory infection classified as "pneumonia of unknown etiology" was provided to the WHO Country office on December 31st 2019 in Wuhan, a metropolis located in China's Hubei province [1,2]. This has led to an intensive outbreak investigation program and to the identification of a novel virus belonging to the Coronaviridae (CoV) family as the cause of this illness. Coronaviruses, of which there are 7 strains, are large RNA spherical viruses with a helical capsid and a lipid envelope that can directly multiply in host cells due to presence of RNA polymerase. They are common in human beings as well as animals (camels, cattle, cats, and bats). The virus that causes COVID-19 is designated as Severe Acute Respiratory Syndrome corona virus 2 (SARS-CoV-2); previously referred to as 2019-nCoV, "CO" standing for corona, "VI" for virus, and "D" for disease [3].

Since the onset of this pandemic, medical and laboratory professionals have completely modified the organization of their work and their relation with clinicians and patients. People are spending more time than ever living and working in the digital milieu propelling AI to an unprecedented level. The second surge of cases worldwide seems more difficult to understand and explain than the first wave. The resurgence of the virus is a huge setback for the countries that had largely succeeded in bringing infection rates down to manageable levels over the summer, after implementing drastic lockdowns. The upside of the present situation is that more tests are available, and people who are hospitalized with the virus are less likely to die. At the same time, the virus's long-term complications, ranging from respiratory disability to cognitive decline, now seem more ominous (the "long Covid"). Our understanding of the mode of transmission is currently incomplete and is constantly modified by various scientific resources on a time-to-time basis. As reported by the WHO, COVID-19 is primarily transmitted between people through respiratory droplets and contact routes [4]. As droplets containing the virus may remain in suspension for several hours as aerosols, and thus increase airborne contamination, proper ventilation and use of disinfectants contribute to the restriction of the spread of the virus. Moreover, recent studies [5,6] suggest that COVID-19 can cause myocarditis, even in people who initially exhibited mild symptoms, or had recovered. These observations are concerning even if rare and still debatable.

Respiratory infections could be transmitted through droplets of different sizes: when the

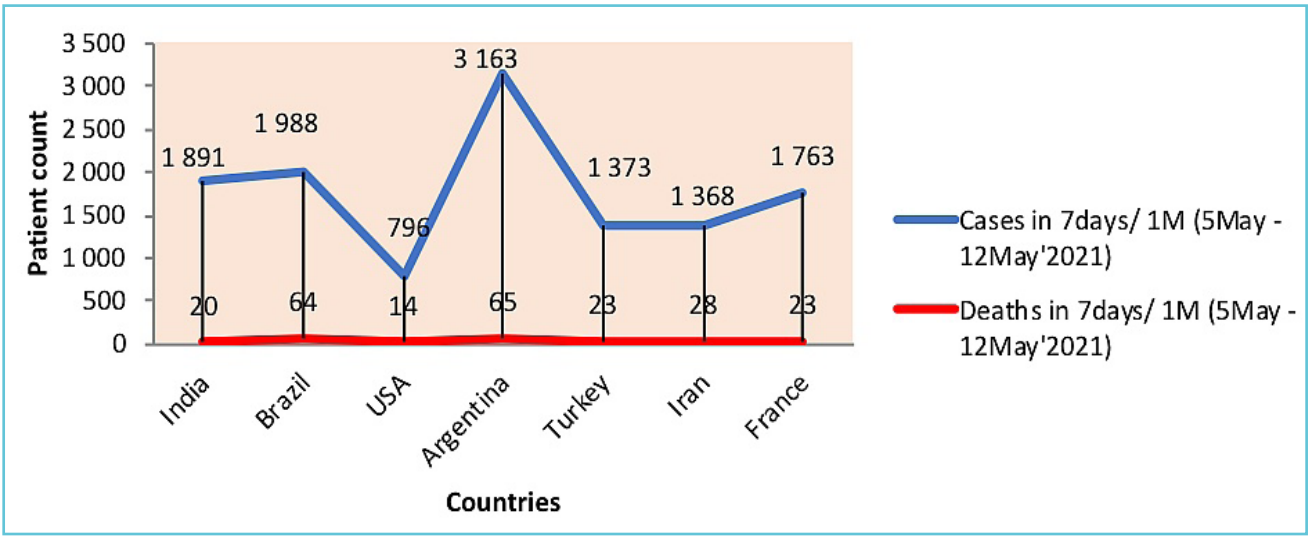
droplet particles are >5-10 µm in diameter they are referred to as respiratory droplets, and when are <5µm in diameter, they are referred to as droplet nuclei. These are respiratory secretions from coughing or sneezing landing on the exposed persons' mucosal surfaces, such as through nose, mouth and eyes [7]. Droplets typically do not travel more than six feet (about two meters) and do not linger in the air, while patients are thought to be most contagious when they are symptomatic. Severe cases may lead to difficulty in breathing or shortness of breath with persistent pain chest and confusion [8].

Worldometer is a resource run by an international team of developers, researchers, and volunteers with the goal of making world statistics available in a time relevant format. Worldometer was voted as one of the best free reference websites by the American Library Association (ALA) and it is a provider of global COVID-19 statistics for a global audience. As per weekly data accessed from 5th-12th May 2021, the total confirmed cases in the world were 5,246,979 whereas total confirmed deaths were 89,174 (Figure 1).

Several strategies, such as medical aid, notification, infection control, testing and radio imaging have been developed to monitor and control the spread of COVID-19. However, emerging technologies with the adequate utilization of Artificial Intelligence (AI) and Mobile Health devices offer new perspectives to face COVID-19 and other viral outbreaks. The adoption of AI and big data is expected to make significant contributions towards facilitating simulations for contact tracing for a better early detection and prevention, online training of healthcare workers, cooperation among regions, and to develop drugs and vaccines [9,10,11].

Looking at Laboratory Medicine, even if implementing new techniques is always exciting, Clinical Laboratory professionals have to adhere to all relevant best practices and regulations. In particular considering that AI and Machine learning already surround us, the first questions are how AI works, what its value is in healthcare and how to initiate an AI project? [11,12].

Figure 1 **Seven day average of confirmed COVID-19 cases and deaths per million population in India, Brazil, USA, Argentina, Turkey, Iran, France, in the period 5-12 May 2021**



Source: https://www.worldometers.info/coronavirus/weekly-trends/#weekly_table.

Moreover, the complexity of human physiology as well as requirements to validate a deep learning system for clinical implementation might be challenging towards machine learning techniques practical applications. Although great promise has been shown with deep learning algorithms in a variety of tasks across precision medicine, these systems are currently far from perfect. In particular, obtaining high-quality annotated datasets is still a challenge for deep learning training. Additionally, it is necessary to introduce definitions and key concepts and how the performance of these new tools can be validated and monitored.

This review focuses primarily on some key technologies such as Mobile Health (mHealth), the internet of things (IoT), telehealth, and artificial intelligence (AI) for COVID-19 modeling and simulation to prevent the rapid spread of coronavirus disease and to maximize safety during the pandemic.

2. ARTIFICIAL INTELLIGENCE (AI) AT A GLANCE

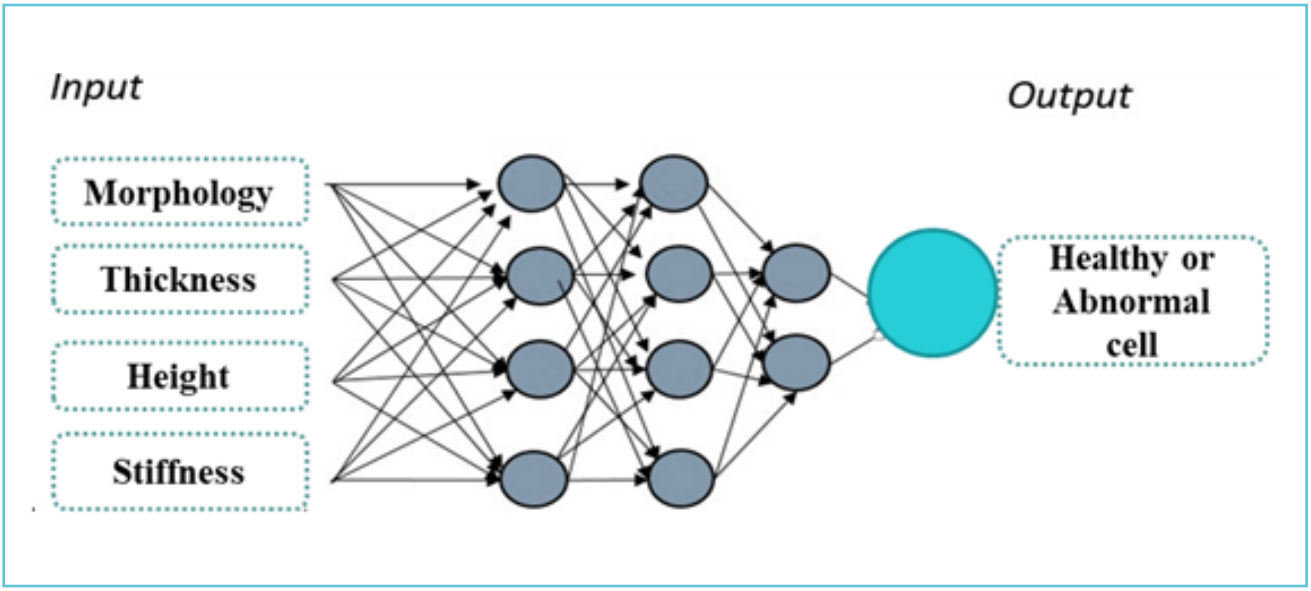
The process for the development of Artificial Intelligence (AI) systems must include basic terminology and definitions, risk evaluation and management, bias as well as assessment of the trustworthiness and robustness of neural networks and machine learning systems. Importantly, ethical and social concerns have also to be addressed. Fundamentally, AI refers to a program with ambitious objectives to understand and reproduce human cognition, creating cognitive processes comparable to those found in human beings. This has been linked to the recent success of Machine Learning (ML) which is a branch of Artificial Intelligence (AI) and computer science that focuses on the use of data and algorithms to imitate the way humans learn, gradually improving its accuracy. AI uses machine learning to analyze data in real time at a speed and volume that no human being ever could. Various applications of ML have been developed in translation, in health to identify diseases and diagnosis. IBM Watson Genomics is a prime example of how integrating cognitive computing with genome-based tumor sequencing can help in making a fast diagnosis. Biopharma companies are leveraging AI to develop therapeutic treatments in areas such as oncology. Medical imaging diagnosis is an advanced application which works on image diagnostic tools for image analysis. Personalized treatments can be more effective by pairing individual health with predictive analytics. More devices and biosensors with sophisticated health measurement capabilities hit the market, allowing more data to become readily available for such cutting-edge Machine Learning (ML)-based healthcare technologies [13].

There are two broad categories of AI: Narrow AI which carries out specific tasks and is what we are used today and General AI which aims to create capabilities and likely won't exist in our lifetime. Artificial intelligence describes a range of techniques for decision analysis and prediction that allow computers to perform tasks typically thought to require human reasoning and problem-solving skills with the help of predetermined rules and search algorithms, or using pattern recognizing machine learning models [14]. Thus, Internet of Things (IoT) involves processing large amounts of data and recognizing patterns in the data. Early AI research in the 1950s explored topics like problem solving and symbolic methods. In the 1960s, the US Department of Defense began training computers to mimic basic human reasoning whereas Defense Advanced Research Projects Agency (DARPA) completed street mapping projects in the 1970s. Over time it allowed connections to data with the help of powerful computers and large enough data sets and processing

information with advanced technologies in the field of life sciences e.g, processing of large datasets generated in different fields of omics such as genomics, proteomics, metabolomics, metagenomics and transcriptomics. The intersection of Machine Learning (ML) with genomics and imaging technologies is an important tool in cancer diagnosis and its prognostication. In one study, an integrative model combining 'omics data with histopathology images generated better prognostic predictions in lung adenocarcinoma patients compared to predictions with image or 'omics analysis alone. However several constraining factors need to be addressed such as the ability to train and validate these algorithms in a clinical setting. Another is the standardisation and aggregation of data (imaging and 'omics) across different research or medical centres before being utilized for patient care. [15].

Artificial Neural Networks are a common type of machine learning inspired by the way the brain works. It consists of a multi-layered network of interconnected units (like neurons) that process information by responding to external inputs. Thus, relaying of information between units requires multiple transfers of data to find connections and derive meaningful data by a mathematical-computational model. It came with promising outcomes in modern healthcare system and empowered diagnostics. [16]. This technique can be helpful for analyzing various pathologies, such as identifying cancer cells or abnormal cells, where the model relates with the input of different features such as cell morphology, height, stiffness and thickness and motility too with the help of powerful advanced automated microscopes that uses advanced tools of image processing based on ML algorithms. In figure 2, the first, second and third hidden layer of neurons for passing information is in Dark BLUE color (fig 2). The prediction with final outcome is depicted in Light BLUE color. The arrows connecting the different circles schematize how the human neural network works and connects to transfer the information from one layer to another one to provide the final output through the output layer [17, 18].

Figure 2 **Artificial intelligence and neural network in analyzing different morphological features such as cell morphology, height, stiffness and thickness to identify healthy or abnormal cancerous cells**



3. AI MATTERS IN THE MODERN WORLD

Over the recent times, there have been huge technological developments in the field of machine learning and especially with artificial neural networks. AI is becoming a ubiquitous technology with endless applications; AI algorithms are designed to make decisions, often using real-time data bringing information from a variety of different sources e.g., sensors, digital data or remote inputs. AI is a game changer capable of doing very fast precise things (and jobs); robotics is one of the most exciting areas for AI development. The same technology has been integrated into a variety of sectors, such as finance, national security, health care, and transportation sectors. Prominent examples being used popularly are Google Maps, AI autopilots in commercial airlines and Social Networking-Facebook [19].

Nevertheless, the developers who are using AI tools, need to engage more with society to provide transparency and standards to address system robustness, data quality and boundaries will increase trust and the ability to interact with a variety of data repositories. Future trends and benefits for AI will see more hands-free applications (e.g., smart glasses). Plagiarism detection for regular text (e.g. essays, books, etc.) relies on a having a massive database of reference materials to compare to the student text. In Plagiarism Checkers, Machine Learning can help detecting the plagiarizing of sources that are not located within the database, such as sources in foreign languages or older sources that have not been digitized. In simple terms, by using techniques like machine learning, big data and analytics. AI systems provide insights into the applications that would not be attainable otherwise. These insights are at the core of AI intelligence [19, 20].

As the pandemic progresses, we are also likely to see the emergence of more applications able to link datasets that we used to train an algorithm to understand how to apply concepts such as neural networks, to learn and produce desirable results. In this context there are many implications for privacy, indeed the linking of datasets may increase the likelihood of patients identification, the profiling of sensitive data, and let data to be available to a broader set of users or data managers. It has been recognized that the reuse of unidentifiable data could potentially serve future public health responses and research. It should be considered that the nature, the accessibility and the utilization of data necessitate transparency and a clear governance processes that should be in place from the outset ensuring that data privacy is protected to the greatest possible degree [21].

4. DOES AI ACT AS A DRIVER OF THE EVOLUTION OF TECHNOLOGY AND BIOMARKERS?

AI has the potential to aid progress in everything from the medical sphere to saving the planet, yet as the technology becoming more complex, questions of trust arise. AI is a fast-changing field full of innovators and disruptors, thus development of norms and standards is becoming a big task and interoperability is vital. AI technologies are developing so quickly that international standards are also needed for transparency and common language. AI has led to the significant paradigm shift in the medical knowledge due to its ability to support decision-making and to improve both diagnostic and prognostic performance for better patient care and outcome. Besides mundane medical tasks, AI in the form of a smart patient assistant is capable of facilitating protracted and mutually beneficial relationships with patients, especially those with chronic diseases that require long remote care [19, 22].

Input data is large and can be varied ranging from socio-environmental, clinical-laboratory to omics-data. The buzz around AI in medical imaging has turned into a boom. There are a large number of startups and health companies working on a wide variety of solutions for example, startups are developing blood testing systems that use computer vision algorithms for the analysis of blood samples. Such tests are used for the diagnosis of a range of disorders including infection, anemia, and certain cancers. The US-based startup Athelas utilizes computer vision technology to help oncology patients track their white blood count and neutrophils. Athelas blood-testing device performs analysis within minutes and requires only a fingerprick of blood [23], the device is FDA cleared for use in point-of-care settings. Merantix® is a German company that applies deep learning to medical issues. It has an application in medical imaging that "detects lymph nodes in the human body based on CT scan images." Thus, it became revolutionary and helpful in identifying small lesions or growths that could be problematic [24]. Cardiovascular diseases are the leading cause of death today and innovations in early diagnostics and treatment of these diseases are relevant. One example of such innovations is an image analytics platform that processes MRI data with AI algorithms in order to evaluate arterial functions. In France, Imageens develops a range of web-based platforms for the early detection and diagnosis of cardiovascular diseases. The company's products process MRI images with AI algorithms in order to create a morphological and functional analysis of the arteries, as well as an evaluation of the left ventricular diastolic function. The latter application is of great value considering that congestive heart failure in the United States afflicts 10 percent of senior citizens and estimatedly costs $35 billion each year.

Millions of people die from stroke every year, and millions become disabled for the rest of their life. Quick and accurate stroke diagnostics based on brain images is crucial for timely and effective treatment. Startups are developing computer vision and artificial intelligence solutions in order to support clinicians in the challenging task of brain image evaluation. Netherlands-based Nico.lab developed StrokeViewer®, an AI-powered cloud-based clinical decision support system that makes a complete assessment of relevant imaging biomarkers within three minutes. The system also enables a rapid image exchange between hospitals and personal devices for the timely triaging of stroke victims.

In these scenarios, AI tools are helpful to predict potential challenges in advance. It further helps to allocate resources for patient education, sensing, and proactive interventions even at home care while maintaining social distancing as an important measure. Several applications have been successfully performed and have helped to improve significantly in both diagnostic and therapeutic applications in relation to personalized care. This is a pivotal time to be involved in AI related technologies to fostering innovation and to help by collective work to propel the wide scale adoption of AI and big data systems. The healthcare investments in AI are increasing, creating or accentuating disparities in the adoption of innovation in healthcare. The implications of introducing and scaling AI in healthcare and its full potential of AI is still being discussed, questions have to be raised about its potential impact on health care professionals and certain specialties, while issues around ethics, use of personal data, and AI-related risks must also be debated in ensuring that citizens fully reap the benefits of AI.

Data is a powerful tool than ever in a pandemic where rightful information can be helpful in predicting the nature of spread of disease and its extent, whereas on the other side it is also helpful in planning and utilizing existing resources to fight the battle against the same. Information

about virus spreads, about how the health and care systems will respond and where they experience hard strain, is needed. Lives can be lost if there are inconsistencies in data, so finding a centralized, fast and efficient way of storing and extracting data is crucial. The so called Data Curation becomes more necessary to resolve four main challenging issues: data integration, electronic dissemination, data sustainability, and metadata. [23,24,25].

5. TELEHEALTH

Telehealth has become an important communication and treatment tool during COVID-19. It is a gateway to how healthcare will be delivered in the future and has enabled the transition to consumer-centric care paradigms. Because of the need to create social distancing in a safe environment and the introduction of reimbursement for virtual visits, telehealth has become an important communication and treatment tool during the COVID-19 pandemic [26].

Telehealth involves the use of communication systems and networks to enable either a synchronous or asynchronous session between the patient and the provider. A virtual care solution usually involves a much broader scope of clinical and work-flow processes, remote monitoring, and several providers over time. Although there is no universal agreement, telemedicine generally refers to the remote delivery of medical or clinical services, while telehealth is a larger platform that includes telemedicine along with remote non-clinical services, such as provider training, administrative meetings, and continuing medical education, in addition to clinical services. Virtual care extends the options to manage the patient well beyond a specific event. High-quality patient treatment is vital, and e-technologies enable healthcare and Lab medicine staffs to collaborate and provide the best possible care for them. Knowledge can be shared in real-time and patient information is consistent because data is being shared digitally, providing the best care possible. Understanding the benefits of telehealth and the delivery of useable, safe and efficient healthcare during the pandemic is paramount [27].

6. MOBILE HEALTH (mHEALTH) TRENDS

Advances within the connected, mobile health sectors and mobile wireless networks globally have led to a series of innovations technologies that address global health-related challenges. mHealth in short for mobile health is the practice of medicine and health care over mobile devices, tablets, personal device assistants (PDAs) and tablet computers. mHealth applications include the use of mobile devices in collecting community and clinical health data, delivery of healthcare information to practitioners, researchers and also for real-time monitoring of patients' vital signs [23]. It has shown to have a positive effect on patient care outcomes, as evidenced by a reduction in adverse events and hospital length of stay. Mobile devices and apps have provided many benefits for HealthCare Practitioners (HCPs), allowing them to make more rapid decisions with a lower error rate, increasing the quality of data management and accessibility, and improving practice efficiency and knowledge [28]. However, HCPs should be aware of the need to use mHealth devices that have been certified for use according to FDA and CE IVD regulations and specialists in laboratory medicine can provide support in addressing ISO and notified bodies requirements.

Global mobile apps market 2020-2024

In news article published by "Business Wire" London [29], it is estimated that the global mobile apps market size is expected to grow by USD 497.09 billion during 2020-2024. As per the report, the COVID19 market impact can be expected to be significant in the first quarter but

gradually lessen in subsequent quarters with a limited impact on the full-year economic growth, according to the latest market research report by Technavio. The development of hybrid mobile apps and growing technology of smartphones will have a positive impact on the market and contribute to its growth significantly over the forecast period (Fig 3) [23, 29].

7. WHAT IS REMOTE PATIENT MONITORING?

Connected health devices run the gamut from wearable monitors, and Bluetooth-enabled scales, to monitor weight and tension, and facilitate continuing health monitoring. They provide health measures of patients and transmit them back to providers to track vitals, to analyze data in real-time manner and facilitate healthcare decisions from a remote distance. Thus, Remote Patient Monitoring (RPM) is a type of ambulatory healthcare helping patients and doctors to use mobile medical devices. RPM technology usually includes monitoring devices such as heart or blood pressure trackers for patients receiving care in the hospital. The recorded or live data is then sent to a physician by using a cloud-connected system with the help of an application on the doctor's phone where they advise and notify staff accordingly. Data transfer should be performed according to data standards and regulation with the example of the European Global Data Protection Regulation (GDPR) and with devices qualified and validated for their technical and medical performances. Considerable additional effort is required to ensure appropriate multi-stakeholder involvement in the development, evaluation and best use of mobile devices and applications for remote monitoring. Remote patient monitoring technologies are akin to telemedicine technologies, since they automatically observe and report on patients, often with chronic illnesses, so caregivers can remotely keep tabs on patient. Emerging technologies are key elements for implementation of reliable RPM, where Sensors and Bluetooth technology are some of its technology driven key components [30, 31].

Figure 3 Technavio market research report showing growing penetration of smartphones to boost market growth

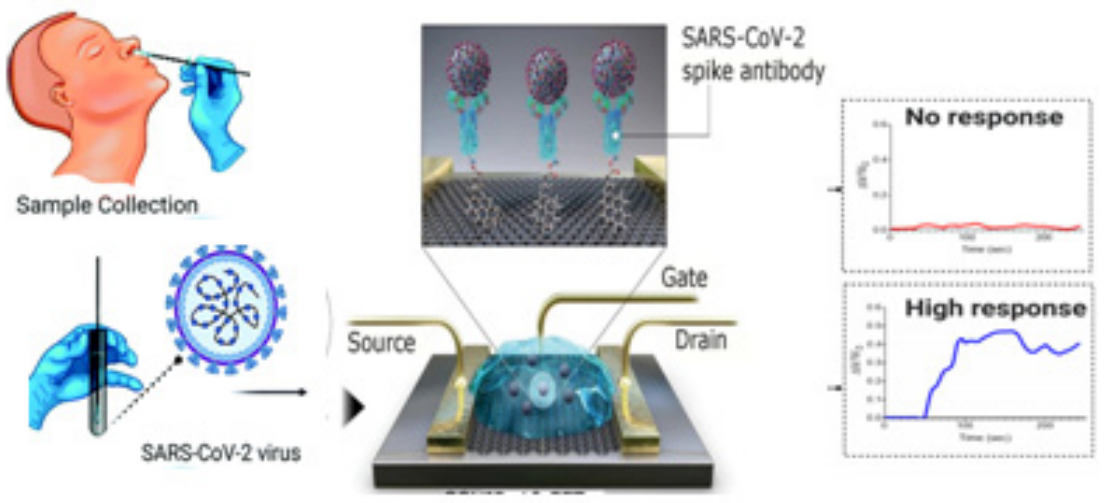
Source of information: Business Wire, Global Mobile Apps Market 2020-2024.

7.1. Biosensors

Wireless sensor networks are being produced to enable IOT technology and are helpful in bridging the physical and digital worlds. In the structured information flow, input data is collected by the sensor devices and sent to the data control center for further feedback through several data channels in parallel. The IOT devices and edge network remains important to keep large set of data records in a structured manner. Under the biological limits, the Biosensors technology can help in detection of specific biological analytes and monitoring of their specific functions. Though the technology and advancement in medical knowledge has grown tremendously, but it always has given associated challenges to overcome. It always necessitates the need based noninvasive, small-sized, portable, and cost-effective sensors for medical application to develop. AI enhanced microfluidics and compact small interactive POCT labs are also set to alter the way diagnostics is carried out. The biosensors applications have shown important role in various fields, such as cancer diagnosis, cardiovascular disease, and wound healing whereas regenerative medicine have also shown a growing interest in biosensors technology ranging from biomanufacturing (such as mass culture cells for organ fabrication or to produce chemicals), organ-on-a-chip technologies and indicators of therapeutic efficacy [32]. Organ-on-a-chip technologies are utilizing microfluidic equipment and small cell clusters of a particular tissue type to replicate behaviour of normal tissue and cells and assessing the response to drugs and other external stimuli. The technology has advanced vastly by using biosensors for real-time monitoring of the behavior of microtissues and organoids. In one more futuristic approach, nanotechnology will be incorporated into biosensors that monitors stem cell differentiation status prior to their transplantation for therapeutic purposes [33].

Further, during the COVID-19 pandemic, there is a surge in demand for promptly testing of mass population with the faster and direct detection of viral pathogen. The modern biosensor-based methods for the detection of the SARS-CoV-2

Figure 4 Modern biosensor-based methods for the detection of the SARS-CoV-2 virus

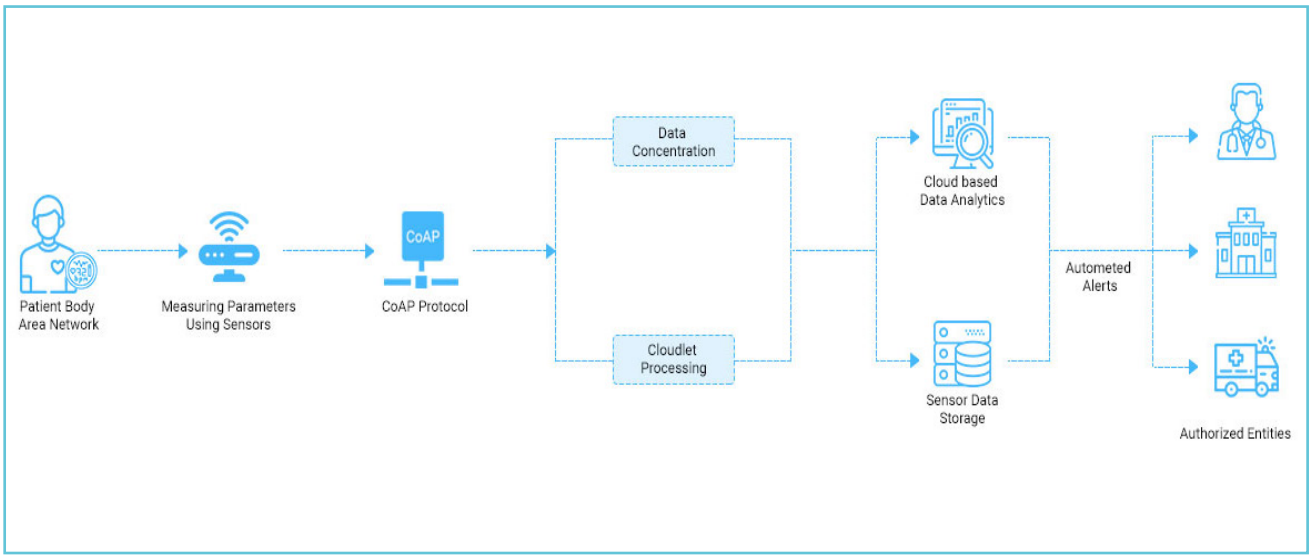


virus are mostly based on detecting virus surface proteins and internal genetic material (Figure 4). In the near future, emerging new technologies such as rapid cum portable RNA extraction preps, CRISPR-Cas based paper strips, nucleic acid hybridization, DhITACT-TR chip-based, graphene-FET, Au/Ag nanoparticles based electrochemical biosensor could pave the efficient ways of rapid, highly sensitive and more promising biosensing cum diagnostic devices for viral pandemics. Thus, a surge in technology and its appropriate usage can help to personalize the medical approach with tailored specific treatments. Biosensing technologies will enable early detection to facilitate reducing healthcare costs, given that prevention is always much less expensive than treatment [34, 35].

7.2. Bluetooth technology

Over the last several years, wireless technologies have made significant progress, and they are now being integrated into many mainstream applications. In particular, Bluetooth is now seeing increased use in a variety of medical applications ranging from home-healthcare devices to operating room equipment. Bluetooth is particularly well suited for cable replacement, allowing for mobile connectivity. It also provides excellent security and reliability and coexists well with other wireless technologies (Fig. 5) and, it is a relatively low-cost technology to implement. They use virtually no power and, because they don't travel far, are theoretically more secure than wireless networks. The first mobile device that incorporated both communication and computing features was the Blackberry, which was introduced in 2002. Subsequently, Apple and then smartphones that run the Google Android operating system were introduced for better functioning and desired outcome. Developers, solution providers, facilities managers and government agencies are turning to Bluetooth technology to implement innovative solutions that help managing the spread, accelerate reopening efforts, and enable safer treatment of patients during the COVID-19 pandemic and disease outbreaks. Bluetooth enabled proximity warnings remind employees and visitors to maintain safe distances to reduce the risk of viral transmission. Thus, flexibility of Bluetooth technology and easy availability in our phones and devices is helping us to minimize the spread and enable safe reopening. [36].

Figure 5 Remote patient monitoring and sensors technology



Personalizing Healthcare with Remote Patient Monitoring at the doorstep is possible with the help of a number of technologies driven healthcare innovations and integrative technologies. It is made efficient by low power wireless technologies like BLE/BT4.0, embedded biometric sensors, wearable monitoring devices, portable telehealth devices, powerful smart phones and Cloud Technology for Electronic Health Record storage and data analytics, e.g., blood pressure cuffs, glucometers, and pulse oximetry. The system can transmit and store the data in secure format systems accessible to clinicians or care givers. It can monitor and flag abnormal readings, as well as produce alert signals where the situation can be responded while reviewing the data and take appropriate actions. Thus, it is also enhancing quality care with reducing medical care cost [36, 37]. Few successful examples are: Aetna, ITriage

This patient-facing mobile app allows patients to directly find information on their health conditions and gives them step-by-step guidance to treat conditions in the most effective way possible. ITriage gives patients directions on whether their conditions require a visit to the emergency room.

Digital Sound Systems Inc. (DSS Inc.)

It gives providers a suite of Emergency Health R-based mobile features that enhance care coordination, patient care and safety. It provides both clinical and administrative tools that range from emergency room and home health mobile care management to automatic billing systems and scheduling tools.

Epic Systems, MyChart Mobile

Its viewable data includes test results, immunizations, medication and health conditions indicated by a provider. MyChart also allows a patient to confirm appointments, pay their healthcare bills, and upload patient-generated data such as fitness metrics from a wearable health device.

MEDITECH, Ambulatory EHR

It allows providers to access complete web charts, giving them instant access to patient records across healthcare organizations on a single mobile device. Providers can tap on a patient's record to view test results, order prescriptions and note the progress of health conditions. It also helps to identify at-risk patients.

8. HOW COULD AI AND mHEALTH BE USED IN FIGHTING COVID-19 AND OTHER PANDEMICS?

8.1 AI and smartphone-based COVID-19 testing

With the need to limit physical contact and trace COVID-positive individuals rapidly, public health authorities worldwide are finding rapid, point-of-care (POC) tests for the novel coronavirus increasingly attractive. Whether it is for testing antibodies or antigens, regulatory authorities are issuing approvals for such kits so as to boost testing capacities. Approvals are limited to kits for use by healthcare workers for now; but several companies are working on at-home rapid tests and could soon follow suit in gaining approvals. From accuracy issues to uncertainties about the virus itself, rapid coronavirus tests have evolved these last months to offer more reliable testing methods. Some rapid COVID tests come in kits that detect antibodies faster through specialized, portable detection devices like the Abbott ID NOW. Rapid tests can be a game changer; in particular when there are a lot of cases and little access to equipped testing facilities. At the beginning of April, India tested only some 150 000 people; one of the lowest testing rates per capita worldwide. Fast-forward a few months to August and the country ran over a million coronavirus tests in a single day.

This boost in testing capacity was possible since Indian authorities adopted antigen assays. And since they help identify individuals most likely to spread the infection, appropriate measures to isolate them can be taken in a timely fashion. These developments can be helpful to enable smartphones to be capable of conducting a coronavirus disease (COVID-19) testing [38].

SANOFI - "at-home test for COVID-19"

"Sanofi" (the French healthcare company) has teamed up with the Californian company "Luminostics" to build an at-home test for COVID-19. They use a glow-in-the-dark nanoparticle that can be picked up by a smartphone's camera to deliver results in 30 minutes without needing a medical professional. Users take a swab up their nose to gather bacteria, and then insert it into a device containing a chemical that includes nanoparticles. If the patient has been infected, the nanoparticles glow and emit a signal that is captured by the smartphone camera and processed using artificial intelligence. People would be given their results through an app which could also connect them to a doctor via video call to discuss a diagnosis. This diagnostic platform will compose of an iOS/Android app with instructions to run the test, capture and process data to display test results, and then to connect users with a telehealth service based on the results. Thus, with this over-the-counter (OTC) solution for COVID-19 testing will be easy to use and with reducing contamination by lowering infection risk [39].

MDBio COVID-19 test kit

It is laboratory-grade diagnostics and couples with smartphone for an automated testing in easy to follow 7 steps. It is an FDA preapproved kit for emergency use. It allows for high capacity testing, and rapid sharing of testing information anytime, anywhere [40].

Apps to determine COVID-19 disease severity

As per "New York University Dentistry (NYU) College of Dentistry", it is stated that it will be "Identifying and monitoring those at risk for severe cases could help hospitals prioritize care and allocate resources like ICU beds and ventilators. Also, these patients can be safely managed at home". The researchers validated the model using data from more than 1,000 New York City COVID-19 patients. The app has been retrospectively evaluated in the Family Health Centers at NYU Langone in Brooklyn, which serve more than 102,000 patients. To make the tool available and convenient for clinicians, they developed a mobile app that can be used at point-of-care to quickly calculate a patient's severity score coupled with a clinical decision support system [41].

AI Tool-Chest X-ray

The "American College of Radiology (ACR)" noted that CT decontamination is required after scanning COVID-19 patients may disrupt radiological service availability and suggests that portable chest radiography may be considered to minimize the risk of cross-infection. Additionally, Chest X-Ray utilization for early disease detection with "ground glass opacities" may also play a vital role in areas around the world with limited access to reliable real-time reverse transcription polymerase chain reaction (RT-PCR) COVID testing [42]. Recently, AI based -Handheld X-ray Camera being developed by HandMed as reported in "JLK inspection". It has an AI based abnormality score and with heatmap visualization of abnormal lesion. This technique is based on the Convolutional Neural Network, which is a class of deep neural networks, most commonly applied to analyzing visual imagery. As per the report, this system has been trained using over 1.1 million chest X-ray data, and it will analyze result report with

integrated telemedicine for earliest response and further action [43].

8.2 Monitoring of pandemics and clusters – tracing

GPS receiver communicates with satellites that orbit the Earth through radio waves. There are currently 32 GPS satellites in orbit – 27 are in primary use while the other serves as backup in case another satellite fails. To determine location, a GPS receiver has to use trilateration to determine your exact location. It means GPS receiver has to follow three simple steps: 1) The locations of at least three satellites above you. 2) Where you are in relation to those satellites. 3) The receiver then uses trilateration to determine your exact location [44]. Smartphones have a GPS chip which uses satellite data to calculate one's exact position. It can ascertain your outdoor position reasonably accurate. When a GPS signal is unavailable, geolocation apps can use information from cell towers to triangulate your approximate position. To be ethical, a contact-tracing app must abide by four principles: it must be necessary, proportional, scientifically valid and time-bound [45].

Apps to curb the spread of COVID-19

COVID-19 outbreak led countries to adopt different strategies to deal with the outbreak. The implementation of mobile software applications in order to monitor people and carry out contact tracing has been a trend adapted on a global scale. EENA -European Emergency Number Association has done comprehensive analysis of 108 COVID-19 apps that are implemented or under consideration in 73 different countries worldwide [46]. They categorized them into five clusters for a common understanding:

- Informational apps - At a time where there is a lot of misinformation/disinformation about COVID-19, these apps provide users with information regarding the disease outbreak (e.g., latest news, fact sheets, guidelines etc.) e.g., Bolivia – Bolivia Segura
- Self-assessment/Medicalreportingapps- It helps to reduce the burden on health-care facilities and ensure that those most in need are getting the right treatment, e.g., India – ArogyaSetu App
- Contact tracing apps - The aim is to prevent quarantine breaches and consequently mitigate the spread of COVID-19. Contact tracing apps are also being used to track infected people e.g., USA – How we feel
- Multi-purpose apps - It combines at least two of the previous clusters i.e., informational apps, self-assessment/medical reporting apps and contract tracing e.g., Ivory Coast - Anticoro
- Other apps related to COVID-19 - It helps in resource management (e.g., masks) and to fight against disinformation e.g., Taiwan - NHI App
- WHO Academy's mobile learning app - It provides critical, evidence-based information and tools to health workers. It is designed to enable them to expand their life-saving skills to fight COVID-19. It serves COVID-19 knowledge resources developed by WHO, including up-to-the-minute guidance, tools, training, and virtual workshops. Importantly, the content is available in seven languages.

The shift in paradigm of internet and technologies has led to the rise of new surveillance technologies, especially drones, cameras, smart phones and robots that are responsible for keeping individuals in the public space in order. At the same time, with the deployment of surveillance technologies, the ethics of privacy protection are now rightly on the agenda. Many

countries in Asia, Europe and other global regions are implementing these applications for monitoring the social interactions via the digital tracking of individuals. Several technologies are in use to achieve desired objectives such as telephone tracking, GPS applications, Bluetooth applications, bank card and transport card systems or even video surveillance and facial recognition; there are many technical means for different purposes. The use of digital tools for tracking individuals raises the risk of harming individual and collective freedoms, in particular respect for privacy and protection of personal data, as well as the risk of discrimination. Digital tools make it possible to quantify, geolocate, map, control and sometimes inform. In a time of health crisis, tracking may be used for three purposes. Firstly, observing collective mobility and confinement practices to reconstruct population movements during confinement period. Secondly, tracking could permit identifying contacts and detecting people who were potentially exposed to the virus. Finally, tracking can create control of individual confinements by observing an individual patient for quarantine and confinement measures [46, 47].

Globally, countries are using the legal and technical means at their disposal to legitimize these systems. The real value of tracking applications comes from their interoperability and their ability to share data with central and local health IT systems which can help statistical analysis, outbreak mapping, capacity management and early clinical intervention for high-risk groups. Furthermore, there has been a huge increase in cyberattacks since the start of the pandemic and especially in healthcare, with ransomware attacks targeting hospitals, government agencies and research centers, among others. This means that these e-platforms and telehealth resources are attractive targets for attackers who wish to spread malware through a health system and causing damage that really disrupts clinical care on a large scale. This poses an immediate threat to patient safety. Thus, the deployment of such devices must be supervised such as GDPR and the e-privacy directive by Europe. They authorize the processing of geolocation data via electronic communication means, provided that they have previously obtained either the express consent of the individuals or have anonymized the data collected. A number of considerations must be taken into account to guarantee that personal data is legally processed and, in any case, it should be remembered that any measure taken in this context must respect general legal principles and must not be irreversible, a condition that can legitimize restrictions on freedoms provided that these restrictions are proportionate and limited to the period of emergency [47, 48].

8.3 Empowerment and prevention of mental health disorders

As per the WHO experts and scientific data available, it is predicted that this pandemic is expected to remain, until it reaches its declining phase. At the same time, social distancing is also an important precautionary measure to prevent pandemic spread. At a time when social distancing has forced individuals to stay within the premises, the mobile applications have helped to supply essentials. Apps are making sure that the lockdown doesn't cut people off basic necessities like groceries, etc. beyond that it can engage, educate, encourage and entertain to help everyone cope during this crisis period. This is where; Telemedicine or Tele Mental Health Services has proved to be promising option for patient care and treatment. Each and every class of society from students to teachers, workers to business got affected with restrictions for lockdown, online teaching, work at home and others [49]. Furthermore, with rising pressure on falling economy with extra financial burdens have opened fearsome

stress related to job, security, future, finances, health, etc. Health issues may include stress, anxiety, fearsome loneliness, and depression which are worsening and raising demands for psychological treatments and counselling sessions. Similar initiatives were considered important and started by different nations e.g., The Australian Government extended previous telemedicine programs and provided additional funding services through Medicare Benefits Schedule dealing with range of mental disorders such as depression, anxiety, stress, anger, grief, etc. during the COVID 19 period. One such service is Betterhelp (betterhelp.com), which adopts texting, video conferencing, telephonic chat, etc. and reduces risk of exposure with remote monitoring and assurance [50, 51].

9. WHAT ARE THE CHALLENGES TO OVERCOME AND HOW INTERNATIONAL SCIENTIFIC SOCIETIES COULD HELP?

While the majority of HCPs have adopted the use of mobile devices, the use of these tools in clinical care has been debated since their introduction, with opinions ranging from overwhelming support to strong opposition. Important concerns were expressed as,

- **Reliability** for making clinical decisions
- Protection of patient data with respect to **privacy**
- Impact on the **doctor–patient relationship**
- Lack of oversight with respect to standards
- Content **accuracy**, e.g., patient management
- **Medico legal** and ethical implications for practitioners
- To be evaluated with regard to **utility** in clinical practice and claimed outcome
- **Lack of data** that support or identify the best approach
- **FDA**-Policy for Device Software Functions and Mobile Medical Applications Guidance. First issued in 2013 and then updated in 2015 and 2019. FDA issued this guidance document to clarify the subset of software functions to which the FDA intends to apply its authority.
- eHealth - The European Commission published a Staff Working Document and a Communication on Digital Transformation of Health and Care, empowering citizens and building a healthier society. These policy documents will give direction to EU activities in this field in the coming years.

These ranges of potential effects of AI on the fundamental human rights are related to social security, data gathering, unintentional bias and discrimination amongst society, lack of public awareness and limited understanding about the consequences. It may lead to unknown ill-informed consequences and subsequent harm later. Thus, ethical concerns in relation to complex nature of artificial intelligence ranges from issues such as job losses from automation, degradation of the environment and furthering inequalities, to issues which may affect our privacy, judgement ability, and even personal relationships. In the view of this rapidly developing technology, all countries approach together and make efforts for preparing robust principle is important. Many independent ethical initiatives for AI have been identified, such as Germany's Institute for Ethics in AI, funded by Facebook, and the private donor-funded Future of Life Institute in the US. Numerous other countries are working for AI ethics councils, including Germany, UK, India, Singapore, Mexico and the UAE [52, 53, 54].

Under the future economic policies framework, it will be required to support workers those were displaced by AI technology due to reduced manpower requirements. Successful AI development requires substantial investment in view of automation and machines, so as to drive government processes with equal knowledge share for all but not to devoid lower income countries. Such example of data sharing and collaborative approaches has been shown by India where they promise to share its AI solutions with other developing countries, and efforts to make it as a fundamental part of education which is available to all. Thus, it will be of prime importance to address these issues in view of futuristic multifaceted challenges associated with AI [53, 55, 56].

10. CONCLUSION

In the face of the 2020 health crisis, it has never been more important for medical labs to remain agile around emerging technologies initiatives. We operate in a world where change is constant. Successful innovation requires not just an understanding of today's needs, but also the ability to project ourselves in the future. Innovators in the field of AI and big data may come from sectors which are not always familiar with medical ethics and research regulation. Issues around patient safety are important to be addressed. The fact is machines are better at numbers than humans, but you will always need a human warrantee to validate and support the process.

As a point of argument and in terms of safety, machines are much better at recognizing things like rare diseases, simply because they are working from a bigger dataset. Algorithms could standardize assessment and treatment according to up-to-date guidelines, raising minimum standards and reducing unwarranted variation.

Emerging technologies can empower patients to manage their condition and can help reducing preventable readmissions. It can improve prescription adherence and allow uninterrupted doctor patient relationship. It is important to remember the potential of emerging technologies to help solve some of our biggest challenges, in particular when they relate to human safety. Several challenges are paving the way of emerging technologies ensuring that aspects such as accountability, responsibility, trust, traceability and human values are handled equally so they can gain wide acceptance. International standards could help to create an ethical foundation for building of a novel health and laboratory ecosystem based on emerging technologies.

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