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Artificial intelligence for COVID−19 and future pandemics: A mini−review

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ABSTRACT

The pandemic of severe acute respiratory syndrome coronavirus 2 has spread very quickly all over the world and has become an unparalleled public health crisis. This unforeseen and exceptional situation has instigated a wave of research to investigate the virus, track its spread, and study the disease it causes. Current methods of diagnosis and monitoring largely rely on polymerase chain reactions and enzyme-linked immunesorbent assay methods. In this hour of crisis, researchers are looking for new technologies to monitor and control such disease outbreaks. Artificial intelligence (AI) is one such technology. Being an evidence-based tool, this technology has the potential to upgrade our disease management strategies and help us to restrict the spread of such diseases. AI can play an effective role in tracking the spread of diseases, screening of the population, identifying patients and developing treatments of diseases. Through this review, we aim to analyze the role of AI in the diagnosis, monitoring and treatment of diseases like coronavirus disease 2019, with most recent updates and assess the prospects of this technology in the management of such diseases.

KEYWORDS: Artificial intelligence; COVID-19; Disease management; Pandemic

1. Introduction

Coronavirus disease 2019 (COVID-19) has affected most of countries in the world and made a significant effect on healthcare facilities and management systems. In March 2020, World Health Organization announced this COVID-19 outbreak, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as 'pandemic' and by the middle of May 2021 more than 160 million cases and nearly 3.33 million deaths due to COVID-19 have been reported globally.

High transmissibility of the virus, ineffective contact tracing, less-understood pathogenesis, a wide range of clinical outcomes in patients, compromised healthcare facilities and delayed diagnosis has hampered the control of this pandemic. Antiviral agents and vaccine remains the very first option for treating COVID-19. Diagnostics based on reverse transcriptase-polymerase chain Reactions (RT-PCR) and Antigen-Antibody reactions are routinely used to track the infection, however, they are laborious, time-consuming and sometimes may gives false-negative results.

In this context artificial intelligence (AI) is an innovative technology that can strengthen our healthcare system and help us to deal with pandemics like COVID-19. AI includes machine learning as well as deep learning, and uses complex algorithms and software to imitate human perception for analyzing and interpreting extensive medical data.

Before the world was even mindful of the danger of SARS-CoV-2, the outbreak of an unknown type of pneumonia was detected by the AI system in the People's Republic of China[1]. Now as the

Significance

Artificial intelligence (AI) is an innovative technology that can strengthen our healthcare system and help us to endure pandemics like COVID-19. In this review, we analyze and emphasize the role of AI in diagnosis, monitoring and treatment of diseases like COVID-19, with most recent updates and assesse the future prospects of this technology in management of such diseases and fighting such pandemic in future.

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outbreak of SARS-CoV-2 has turned into a pandemic, the tools and the technologies based on AI can be beneficial in managing stage of disease management *viz.* detection of the virus, prevention, response analysis, recovery from the disease and the research acceleration[2]. AI is useful to tracking the virus spread, identify the patients at higher risk and predict the mortality risk by analysing data of previous patients. This modern technology, could bring more benefits to population screening, forecasting, vaccines and drug development and decrease workload of health workers[3,4].

In this review we aim to analyze the role of AI in diagnosing, monitoring and treating diseases like COVID-19 and highlighting its potential role in preparing us for preventing and fighting such pandemics in the future.

2. Approaches to diagnosis of COVID-19 like outbreaks

Quick and accurate detection of virus carriers and screening of asymptomatic carriers are all important for controlling the spread of COVID-19. Various diagnostic approaches are available for the detection of COVID-19.

RT-PCR is a mostly used routine technique to detect SARS-CoV-2 virus, RT-PCR uses specimens from respiratory tracts *viz.* sputum from lower respiratory tract and throat and a nasopharyngeal swab from the upper respiratory tract. This PCR based technique generally takes up to 2 days to give the complete result and sometimes may give false negative results also. Hence serial testing may also be required to eliminate false negative results[3,5-7].

Expect for RT-PCR, a few of other techniques like next generation sequencing, loop-mediated isothermal amplification (LAMP), serological methods and imaging techniques are also used for the detection. Next generation sequencing test facilitates the sequencing of the whole genome of the virus, thus helps in diagnosis. This method is of great value to identify unknown pathogens and also helps finding a mutation in the pathogen's genome within a short duration. However, its higher costing and the chemicals needed restrict its uses in routine laboratory diagnosis[8].

LAMP, a relatively novel method for the detection of COVID-19 includes molecular amplification of genomic material with high efficiency and requires only a short interval. LAMP is a very easy-to-use technique that may provides sensitive, reliable, and also specified results within a short time period as compared to other traditional methods. However, it tends to give a false-positive result because of cross contamination or forward contamination[6,9].

Serological methods use blood samples to detect the infection. The blood sample contains either a measurable antibodies concentration or virus-specific antigens. ELISA-based detection kits have also been developed by utilizing antibodies that are against spike, nucleocapsid or membrane and enveloped proteins and are considered as a sensitive diagnosis method[6]. However, this method may take up to 3-4 days, and it may also provide false positive result.

For clinical diagnostics, equipments like X-RAY, MRI and thoracic CT are easily accessible and provide valuable information about the disease conditions[3,4]. CT scan imaging, is one of the important technique for diagnosis of COVID-19, as it presents results before the appearance of clinical symptoms[6,10]. However, scanning and imaging techniques are demonstrative and not confirmatory tool and have limitations like the inability to differentiate with similar cases of other pneumonia (viral or bacterial) and the problems associated with abnormal imaging[6].

Although there are a number of methods that are accessible to detect the virus and to fight against this infection in this current pandemic outbreak, but these diagnostic techniques have their limitations. The rapid spread of COVID-19 strongly demands sensitive and cost-effective diagnostic techniques, and a lot of researches are diverted towards this goal.

3. Non-AI based traditional approaches and their limitations

Non-AI based conventional approaches could be used when a symptomatic patient reach out to the physician. The physician could make diagnosis based on the symptoms and checks for multiple matches with disease-specific symptoms (Figure 1). A positive outcome leads to diagnostic tests for confirmation.

At this stage, the specimen is taken from the patient with the help of healthcare staffs, and the patient's background data, last travelling history and symptoms are recorded manually. Healthcare workers are also engaged in contact tracing for identification, assessment and management of people who were at high risk of exposure to the infection. They also reach out to those people to inform them about the high risk and advise them to quarantine themselves. Manual contact tracing also needs self-monitoring of signs and symptoms. An effective health management system is essential to manage and monitor such extensive medical data and to interrupt the spread of disease.

For positive confirmed cases, the patient is quarantined and symptomatic treatment is initiated. In hospitals nurses, doctors and healthcare workers are appointed to monitor the situation of the patient by regular visits. This increases the probability of transmission of diseases and keeps them at high risk. These limitations call for the inclusion and integration of novel technologies for healthcare, such as AI.

4. AI-empowered approaches for the management of COVID-19 like diseases

AI is the application of software and programmed machines that can learn, assemble, manipulate, communicate and interact in social settings[11]. Machine learning and deep learning are the subsets of AI and are very helpful in fighting COVID-19 and similar diseases. With the help of AI, some modern, accurate and efficient steps may be taken for effective management and control of disease

outbreaks (Figure 2). We will be discussing the potential role of AI in preventing and fighting COVID-19 and assess the future prospects of this technology in management of such diseases in the future.

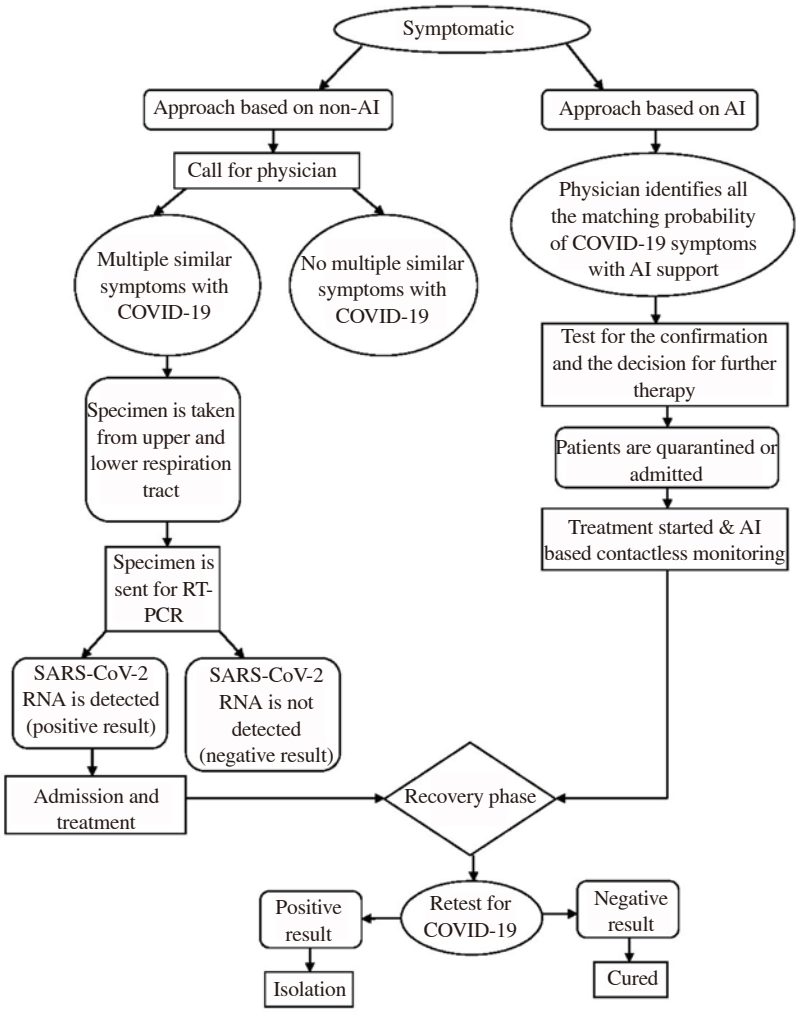

Figure 1. AI and non-AI based traditional approaches to disease management.

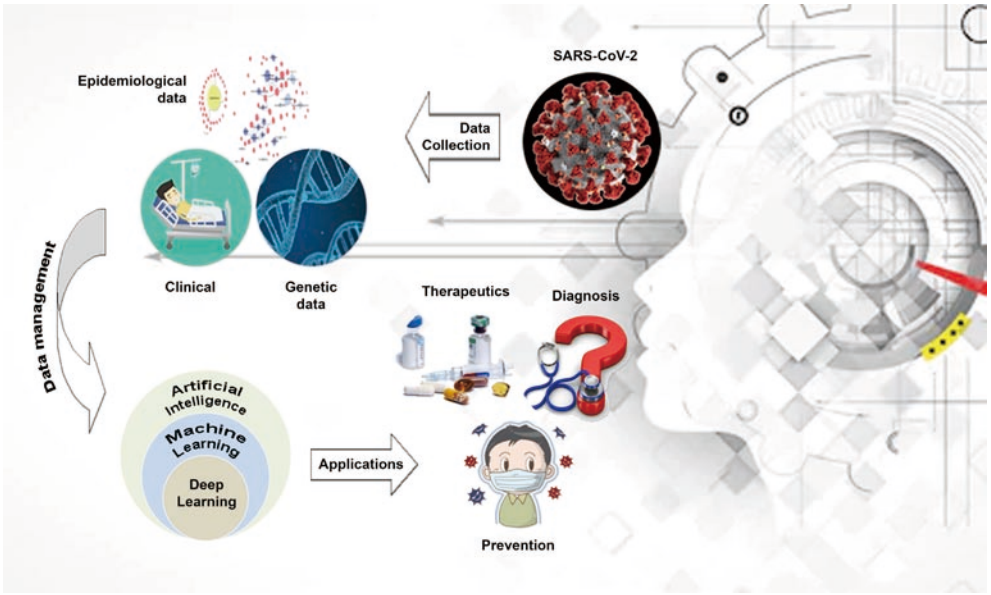

Figure 2. Some modern, accurate, and efficient steps may be taken for effective management and control of disease outbreaks with the help of AI.

4.1. Disease monitoring and diagnostics

AI has helped in developing a smart diagnostic system for coronavirus disease through algorithms. For symptomatic COVID-19 patients, chest CT is an important tool of assessment and diagnosis. However, chest CT findings might be normal at the early stage of the infection, emphasizing the need to include clinical data during diagnosis. Mei *et al.* devised algorithms to meet this need by combining chest CT reports with a history of exposure, clinical symptoms, and results of laboratory diagnosis. They reported, that the proposed AI algorithm, combined with CT scan reports and clinical diagnosis gave great results when tested a set of 279 test cases[7].

Belfiore and his team suggested that, chest X-RAY and CT might be employed for diagnosis in asymptomatic COVID-19 patients. CT examination in the patients with COVID-19 includes the application of high-resolution CT (HRCT). Integrating AI software with HRCT can facilitate CT diagnosis and help in classifying infections based on various severities, combining structured reports, arranging quantitative and target assessments of the lung lesions. They introduced an example of AI application for radiologist (Thoracic VCAR software, GE Healthcare, Italy) to detect of SARS-CoV-2 which can give a sensitive, quick and brief report. Although CT has a higher sensitivity when identifies lung lesions, but it is not specific for diagnosis of COVID-19 and similar viral infections. An AI software that can quantitatively assess the extent of affected and non-affected lung parenchyma is needed[10].

Gozes *et al.* utilized deep learning and made an image analysis system to classify results of non-coronavirus and coronavirus cases. They presented a system that uses powerful 2D and 3D models based on deep learning, to modify existing AI models and merge medical understanding. Their initial study, exhibited that this AI-based image analysis can reach to higher precision for the detection of disease and also for monitoring the disease burden[12].

Many new types of smart CT systems and X-RAY are supplied with cameras which are much helpful for monitoring the patients and facilitate the application of a contactless scanning. In COVID-19 outbreak, those modern gadgets facilitate the application of a contactless scanning flow. From the control room, technicians can easily monitor the patients *via* a camera that provides live video data. Here, by identifying the patient's pose and shape, AI can make this process automatically, with the help of some visual sensors like RGB (a red, green, and blue colour model), Time-of-Flight pressure imaging[3].

Imran and his co-workers developed AI4COVID-19, an AI-enabled diagnostic application for preliminary diagnosis of COVID-19 using cough samples. This application records the cough sounds of users, which are transmitted to the cough detection engine for checking the quality of the sample and the result will be rendered to the user. Researchers concluded that, this application can identify the difference between the coughs of COVID-19 and non-COVID-19 patients. They further clarified that AI4COVID-19 cannot be used as a clinical-grade diagnostic tool. Alternatively, it offers a tool for contact-less screening and could be deployed anytime, by anyone and anywhere[13]. There are others AI application of AI like BlueDot, COVID-19 chatbot, CRUZR robot, EpiRisk as presented in the Table 1, and those are designed to help disease diagnosis and monitoring.

4.2. Drugs and therapeutics

The most needed function of application of AI is to assist researchers in finding a potential therapy to protect citizens and control the spread of disease. AI can assist in designing vaccines and medicines at a quicker rate than expected and can likewise be useful for clinical trials of vaccination.

Recently, AI has been applied for virtual screening of both repurposed drug candidates and new chemical entities for treating COVID-19. Repurposing drugs can anticipate and manipulate the off-target biology of existing medicines or interconnected biological pathways that are safe and could thus be tested in new clinical trials quickly. A previous study tried to repurpose candidate drugs

Table 1. AI-based programs and their applications in disease management.

AI application	Usage phase	Function	Reference
AI4COVID-19	Diagnosis	It can identify difference in coughs between COVID-19 and non-COVID-19 patients.	[13]
AlphaFold	Therapeutics	It helps the prediction of protein structure of coronavirus and vaccine development.	[14]
BlueDot	Detection/Prediction	Data analysis to map and prevent diseases.	[1,2]
COVID-19 Chatbot	Response	The chatbot asks a series of questions, fast analyzes reported symptoms, and determines high-risk group.	[2]
COVID-Net	Detection	A deep convolutional neural network tailored to detect the COVID-19 cases.	[15]
COVNet	Detection	COVID-19 detection neural network with a high accuracy; help in extraction of visual features from the volumetric chest CT scans to detect COVID-19.	[15]
CRUZR robot	Response	Helps material transportation by drone; robot helps in high exposure task in hospitals.	[2]
EpiRisk	Prediction	Calculates a person's infection probability.	[2]
SUMMIT	Therapeutics	It's a supercomputer, used in high-throughput screening campaign and identification of the small molecule binding with protein receptor complex or protein alone.	[16]
Thoracic VCAR software	Detection	A great instrument for the radiologist in the detection of SARS-CoV-2	[17]

by experimentally linking 66 human proteins to 26 SARS-CoV-2 proteins. Network-based model simulation is a key computational method for studying the virus-host interactome, in addition to wet-lab approaches. By studying the genome sequence of three major coronavirus family members and then comparing them to human disease-based pathways, a previous study identified 30 drugs for repurposing[14]. Zhou *et al.* also presented an integrative, antiviral drug repurposing methodology, combining network-based methodologies with repurposed drugs[15].

Multi-task deep learning models have also been used to identify existing drugs that may target the main proteins, spike protein, and especially the main protease (3CLpro). Cyclica's development and mining of PolypharmDB, a database of known drugs and their expected binding to human protein targets, revealed off-target applications of 30 existing drugs, for example, against the viral protein 3CLpro and the ACE2 binding site[14,16].

Machine learning-assisted molecular docking is one of the most popular methods for virtual screening. This procedure usually necessitates the following: (1) Druglike or approved molecules dataset; (2) Target crystal structure or homology model; (3) Molecular docking program; (4) Molecules that have been found to match the binding site of various SARS-CoV-2 proteins, which are needed for viral replication and infection, *via* docking. The host ACE2 receptor and TMPRSS2 protease, as well as PLpro, RdRP, Spike Protein, and $3CL^{pro}$ were all screened. Ton *et al.* created and used the deep docking network technology approach to find at least 1 000 protease inhibitors. They did not have a novel docking score because they used the QSAR to train their model[14,17].

Giant Baidu, a Chinese multinational company in partnership with the University of Rochester and the Oregon State University has devised an algorithm to study protein folding. They claim that the algorithm is faster than the traditional algorithm in the prediction of the structure of the virus secondary ribonucleic acid (RNA) and also gives information about the spreading of the virus. Examining the secondary structural changes between homologous RNA virus sequences (for example, bats and humans) can enrich our knowledge about viral spread across species. This rapid analysis of viral structure can notably shorten the duration for designing a potential mRNA-based vaccine, which is more stable and effective, giving a chance to save a huge number of lives[18].

Deep Mind, an association of Google Company, has developed a program 'AlphaFold' for the prediction of the protein structure of the coron avirus that can assist in the development of vaccines[19]. Another team of researchers has reported the use of AI-equipped IBM supercomputer SUMMIT for drug design of SARS-CoV-2 antivirals. The group is utilizing a computational model of the spike (S-protein) of the coronavirus to understand its interaction with the human ACE2 receptor. They proposed the application of SUMMIT for screening and identification of molecules having an affinity towards protein molecules or to the protein-receptor complex. This can lead to the rapid identification of small molecules and is capable to limit the interaction of the virus with the host cell. Using this method, a large number of molecules can be modelled and tested continuously[20].

In another study, Ke and the coworkers reported different models to repurpose drugs with different datasets. They established an AI platform to identify old drugs with potential activity against the coronavirus. They tested the activity of AI-predicted drugs against the coronavirus in an *in–vitro* cell-based assay. Those results were given to the AI system to solve relearning problems and generate a reframed AI model for searching old drugs. Taking advantage of AI, they identified some drugs that are older but active against the coronavirus[21].

Machine learning, a subset of AI, can also help to discover drugs very quickly for the treatment of COVID-19. Benevolent AI, UK AI organization, and AWS client, turned its platform towards the body's response in the understanding of coronavirus. They used their AI drug discovery platform to identify the approved drugs which may inhibit the coronavirus progression potentially. They also used machine learning to derive relations between genes, disease, and drugs, which helps understand drugs applicable for the treatment of disease[22].

4.3. Contact tracing

AI-powered mapping systems can help identify the flow of travel across high-risk areas and monitor the early spread of the virus. It can help analyze the infection level by identifying the clusters and 'hotspots'. It can also assist in predicting the future course of this pandemic and its reoccurrence[4]. The location positioning system based on AI runs on a bluetooth message network system, which automatically locates the position of potential carriers, offering indirect and direct contact tracing[23]. Srinivasa *et al.* have proposed an algorithm and could quickly identify those persons who might have mild symptoms. Their proposed modelling technique could be a major help for the monitoring population under quarantine[24]. Several other such programs and applications are mentioned in Table 1. The AI-driven analytical device can empower doctors, technicians, and users with real-time data of disease spread, which can further augment the preparedness and efforts to control the disease spread.

4.4. Decreasing workload

Conventional disease management systems largely depend on healthcare workers for data collection, diagnosis, and monitoring of patients. This keeps them overburdened and at high risk. Integration of AI in healthcare can address this problem to a great extend.

A Chinese company, Alibaba DAMO Academy, has developed an AI system for the recognition of the coronavirus with an accuracy of 96%. As indicated by the company, the system can scan 300-400 times, expected to identify COVID-19 patients in 20-30 seconds, while the identification typically takes 10-15 min by an experienced doctor[25]. AI could shorten the required time for designing the diagnostic kits based on the genes of the virus to a few weeks, which otherwise takes a longer time[26].

Smart CT systems and X-RAY with cameras have been developed

through modern technology and are very much beneficial for monitoring patients and contactless scanning. Technicians can monitor patients *via* camera with live video data[20]. Besides, since it is a contactless technology, it can reduce the risk factors for doctors as well as healthcare staff while monitoring the patients and also decrease the workload.

5. Prospects and conclusion

The application of AI in healthcare is just in the beginning stage, but it is developing fast. It has gained a lot of interest from researchers in the current condition of a pandemic. It is proved to be a helpful tool for identifying the infection and for monitoring patients infected with SARS-CoV-2. It helps track the spread of this pandemic at different stages. AI-based image acquisition has shown its efficiency and effectiveness. Looking forward, it is very much expected that more AI-based image acquisition may be integrated into this workflow to provide better scanning quality by reducing the dosage of radiation consumed by patients. Due to this pandemic, the economic status of many countries is declining. With the help of AI, we can restore the economy too.

Here, in our article, we discussed the application of AI-based technologies to contain such pandemics in the future. AI could help prediction of the disease, diagnosis, monitoring, drug development and prevention of the COVID-19 like pandemics. In conclusion, AI is more beneficial than conventional methods and can revolutionize the healthcare system worldwide.

Conflict of interest statement

The authors report no conflict of interest.

Authors' contributions

A.D.: Presented the idea for the article, performed the literature search and analysis; N.G.: Drafted and critically revised the work.

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