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Artificial Intelligence and Big Data in Fighting COVID-19

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ABSTRACT

COVID-19 was caused by SARSCoV-2, spread rapidly, and became a global pandemic within a few months. Almost all countries have tried preventing or mitigating the risks of COVID-19 using various advanced technologies such as Artificial Intelligence (AI), big data and Big Data analytics, robotics and autonomous robots, blockchain technology, Internet of Things (IoT), Internet of Medical Things (IoMT), and 5G networks. This paper mainly introduces the applications and progress of AI such as deep learning (DL) in testing and diagnosis; drug repurposing, drug discovery, and vaccine development; and the prediction of COVID-19, the prevention of its spread, and public sentiment analysis. Big data in mitigating the risk of COVID-19 and big data combined with AI in fighting COVID-19 are presented. Challenges of AI applications in COVID-19 as well as future prospect, some shortcomings of AI technologies and Big Data analytics, and AI combined with blockchain technology for combating COVID-19 are also discussed.

Keywords: Artificial intelligence; Big data; COVID-19; SARSCoV-2; Machine learning; Deep learning; Convolutional neural networks; Blockchain

INTRODUCTION

The impact of disturbance in business due to the COVID-19 pandemic has led to challenges in supply chains and supply chain management, which has resulted in a fast drop of some economic indicators such as global gross domestic product and productivity. COVID-19 has been the biggest disturbance to the economy in the world. It has brought considerable challenges to hospitals, ventilators, and ICUs [1] and huge risks to people's lives. According to the conclusion of an Italian report, there is a substantial vitamin D deficiency in patients with COVID-19 infection. In addition, there are protective effects of sunlight exposure against COVID-19 mortality. Further research is required to validate this [2].

Reverse transcription–polymerase chain reaction (RT-PCR) method for diagnosing COVID-19 is sensitive; however, it has limitations for clinical diagnosis and treatment. Droplet digital PCR (DDPCR) has a better performance in detecting low-viral-load samples [3]. Proteins associated with the inflammatory response, cell damage, and blood coagulation have been recognized as potential predictors of COVID-19 mortality or severity. The quick utilization of plasma proteomics or throat swab proteomics in a regulated discovery proteomics environment will be a significant part of future development for fighting COVID-19 [4].

Since twice the number of staff and instrumental equipment is needed, a COVID-19 rehabilitation unit was twice as expensive as other units. COVID-19 rehabilitation units need to be equipped and organized according to the clinical and rehabilitative requirements of patients, following certain procedures to stop the spread of infection among workers and patients [5]. Rehabilitation for COVID-19 needs to start from acute and early post-acute care and be continued in the post-acute and long-term rehabilitation phase. Global Rehabilitation Alliance has urged decision makers to guarantee that rehabilitation services should be available for all patients with COVID-19 in the acute, post-acute and long-term phase. Rehabilitation services need to be equipped with personal protection equipment and follow strict hygiene measures [6].

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Mobile-based rehabilitation (MBR) uses advanced technology for communication between patients, therapists, and caregivers. It helps medical professionals to monitor patients' condition and make clinical decisions. Various mobile-based apps can be employed in neurological patients' rehabilitation during the COVID-19 pandemic [7]. The advantages and disadvantages of MBR are listed in Table 1 [7].

Advantages	Disadvantages
MBR is convenient and flexible to access at any time because videos can be downloaded and saved to mobile devices.	Possible problems with network connectivity.
Easy and cost-effective for rehabilitation due to reduced time consumption and travel costs.	Difficult to gain access to the rural population due to poor availability of resources
Maintained social distancing due to the digital interaction/indirect interaction between a therapist and a patient.	Difficult for a patient with psychological problems, cognitive impairment, or learning disabilities.
Entertaining approach to rehabilitation through games and virtual environments.	Impossible to have a manual contact with a physiotherapist.

Table 1: Advantages and disadvantages of MBR.

COVID-WAREHOUSE is a data warehouse (DW) that was developed to store, integrate, and model COVID-19 data. This DW supports On-Line Analytical Processing (OLAP) and permits the extraction of selected data for analysis. Preliminary research indicates that COVID-19 has considerably spread in areas with a high-level concentration of particulates in the air or regions without wind and rain. COVID-19 has posed various challenges in the following areas: diagnosis and therapy, healthcare logistic, drugs and vaccines, virus mutations, ICUs (Intensive Care Units) management, molecular basis of the disease, large scale tracing of people's contacts and movements, etc. [8].

A block chain-based healthcare information exchange (HIE) system has been proposed that strengthens electronic medical records (EMR) and provides better security and privacy protection. The block chain of EMR utilizes the method of "off-chain storage and on-chain verification" due to the large size of records. Original records are stored in the hospital's database. A copy of records with only hash values and doctor's and patient's signatures proves the consent of both the entities [9]. A framework was proposed based on disruptive technologies for COVID-19 analysis. The disruptive technologies include Big Data analytics, AI, 5 G, block chain, Internet of Things (IoT), Internet of Medical Things (IoMT), drone technology, Industry 4.0, virtual reality (VR), and autonomous robots [10].

Safe transportation is significant during the COVID-19 pandemic. The propagation rate usually depends on the contact intensity that is related to the contact duration and frequency. A strategy was proposed to deal with crowded train stations, carriages, and platforms that are very susceptible to the disease dispersion. The strategy also exploited technologies such as Bluetooth, WiFi, Ultra-Wideband, and radio frequency identification to capture the data of various age-group travelers and pseudonymized the data for real-time decision analysis based on AI [11]. Since there are asymptomatic carries and some patients discharged from hospitals got SARS-CoV-2 virus infection again, real-time SARS-CoV-2 detection and tracing are important. SARS-CoV-2 sensing reinforced by IoT and AI is significant for COVID-19 management due to the following advantages [12]:

- IoT in SASR-CoV-2 bio sensing helps develop wireless systems for point-of-care (POC) diagnostics.
- POC diagnostics based on AI and IoT helps manage COVID-19 in a personalized manner.
- The integration of AI, IoT, and Nano enabled SASR-CoV-2 bio sensing will provide a good platform with personalized and intelligent management for COVID-19.

The main purpose of this paper is to introduce the applications, progress, and challenges of AI in combating COVID-19, big data in mitigating the risk of COVID-19, and big data combined with ai in fighting COVID-19. The remainder of this paper will be organized in the following sections: the second section introduces AI in combating COVID-19, the third section presents big data with AI in fighting COVID-19, and the fourth section is a conclusion.

ARTIFICIAL INTELLIGENCE IN COMBATING COVID-19

Testing and diagnosis

COVID-19 is typically confirmed by RT-PCR. RT-PCR protocols have been recommended for diagnosing COVID-19. The performance of RT-PCR can be affected by 1) sufficiency of samples collected, 2) variability in the sites of specimen acquisition, and 3) low levels of shedding during incubation or early infection. RT-PCR has high false negatives and testing is time-consuming. Sometimes, there are not sufficient supply of RT-PCR kits. All these may cause troubles for patients [13,14].

Many experts suggested using the chest computed tomography (CT) for suspected cases since an initial chest CT may show abnormal findings regarding COVID-19. In addition, CT has features such as high positive rate, fast turnaround time, and more detailed information associated with the pathology. Based on CT scans, an AI system was designed that employs a multi-scale convolutional neural network (CNN) and evaluate its performance. Results demonstrated that AI has promising diagnostic performance in detecting COVID-19 only using a small number of CT data [13]. Many clinical applications of AI in COVID-19 focused on imaging-based diagnosis [15] [Table 2] lists some AI applications in COVID-19 diagnosis using CT.

Model or application	Places in study	Sample size	Evaluation
InceptionV3, ResNet50, and	Global	Chest X-ray images (50 for normal persons	Accuracy for InceptionV3: 97%

Inception ResNetV2		and 50 for COVID-19 patients)	ResNet: 50 98% Inception-ResNetV2: 87%
COVID-Net: A deep CNN	Toronto, Canada	16,756 chest radiography images (13,645 from patients)	Accuracy: 92.4%
Real-time RT-PCR assay	Thailand, Hong Kong, etc.	340 clinical specimens from 246 people (patients with confirmed infection or suspected infection)	Potential detection limit of <10 genomic copies per reaction
3D deep learning model	China	618 CT samples (219 from 110 Patients)	Accuracy: 86.7%
2D deep CNN	China	970 CT volumes of 496 patients (with confirmed infection of COVID-19)and 1385 negative cases	Accuracy: 94.98% Specificity: 95.47% Sensitivity: 94.06% AUC: 97.91%
Modified inception transfer-learning model	China	1065 CT images (740 viral pneumonia and 325 COVID-19)	Accuracy: 79.3% Specificity: 83% Sensitivity: 67%
COVNet for COVID-19 detection	China	4356 chest CT exams from 3322 patients	Accuracy: 95%

RT-PCR: Reverse Transcription Polymerase Chain Reaction; CNN or ConvNet: Convolutional Neural Network; AUC: Area Under the receiver operating Characteristic Curve.

Table 2: Some applications of AI in COVID-19 diagnosis using CT.

A B5G framework was proposed that used the high-bandwidth and low-latency of the 5G network to detect COVID-19 based on CT scan or chest X-ray images and develop a surveillance system to monitor mask wearing, social distancing, and body temperature. Three DL models, including Inception v3, Deep tree, and ResNet50 were used in the framework. DL combined with B5G improves regional access to medical information, helps medical staff to diagnose patients remotely, permits physicians outside locked-down epicenters to handle X-ray and CT specimens. A centralized edge cloud-based DL platform is needed during the COVID-19 pandemic. The platform at the edge of the hospital network enables large real-time data analysis and infers reliable results. Huge live and multi-dimensional datasets of COVID-19 can be exchanged via 5G networks and used by deep neural network groups across the world [16].

With full blood counts and an Artificial Neural Network (ANN) model, patients with SARSCoV-2 can be identified with a good accuracy. These patients have a characteristic profile pattern of immune response and changes in various parameters measured in the full blood counts that can be obtained from rapid and simple blood tests. Because symptoms due to SARSCoV-2 at the early infection stage have an overlap with other infection conditions, parameters of the blood counts can be analyzed to distinguish viral types earlier than RT-PCR. This method has the potential to improve the initial screening of patients [17].

One problem of AI is that it often requires a lot of data to achieve results with accuracy, which is especially true for DL that often suffers from over-fitting. Diagnosis for COVID-19 with RT-PCR is not very accurate. Other methods such as CT and X-ray imaging, blood and urine tests, etc. can help diagnose the disease. It has been suggested that ensemble methods should be developed through inputting all kinds of discriminative data from various tests to achieve a better accuracy [18].

Multiple modalities help determine whether a patient is infected with COVID-19 and they include CT, magnetic resonance imaging (MRI), ultrasound, etc. An advantage of the imaging modalities is the visual access. However, they cannot present a "risk assessment", which is a disadvantage. ML (e.g., DL) enhances the information provided by the imaging modalities, leading to a more accurate characterization of the disease process and the tissue. Medical imaging with AI can improve the stratification of risk and diagnosis, speed up evaluations, facilitate the monitoring of the disease, etc. [19].

A CVOID-X framework was presented to identify COVID-19 based on DL classifiers. A DL model with COVID-19 detection using Neautrosophic classifier was created to extract visual features from volumetric exams for detecting COVID-19 [20]. The COVID-19 infection was analyzed with DL models and laboratory data. Six various models were trained, including ANN, recurrent neural networks (RNN), CNN, long short-term memory (LSTM), CNNRNN, and CNNLSTM. Various laboratory data were analyzed with the six DL models. Classification was performed and performances of the models were evaluated with accuracy, recall, AUC, precision, and F1-scores, respectively. Ten-fold cross-validation and train-test split methods were used to further validate the models [14].

Digital image analysis recognizes patterns quantitatively with good precision. DL can recognize COVID-19 from other atypical and viral pneumonia diseases with a good accuracy. Ten well-known CNNs were used in diagnosing COVID-19. It was shown that CNNs can perform classification with improved performance [21]. CNN helps recognize features in chest X-ray images of COVID-19. A major shortcoming of the neural networks is that they rely on the availability of labeled data. A COVID-19 dataset often has inaccurate or incomplete labels and new data are continually added to an existing dataset.

Unsupervised learning, specifically a self-organizing feature map (SOFM) network, can be used to perform clustering for chest X-ray images of COVID-19 and successfully extract features. The biggest strength of unsupervised learning is that data are not required with labels because the neural network clusters a given input space according to similar features [22].

AI and blockchain can be combined with POC diagnostics to perform self-testing of patients in isolation due to COVID-19. A low-cost self-testing and tracking systems based on blockchain and AI for COVID-19 has been recommend. The AI-blockchain system enables a transfer of test results to alert authorities and provide all completed tests as well as the numbers of positive and negative cases. The in-built geographic information system in mobile devices enables the tracing of individuals who are infected and tested positive [23].

Drug repurposing, drug discovery, and vaccine development

Drug repurposing refers to using available drugs for the treatment of a never-considered therapeutic indication such as COVID-19. AI-based drug repurposing is fast and cheap, minimizing failures in clinical trials. Drug repurposing can be performed using DL. A repurposed drug can enter an advanced phase for trials directly without toxicity tests and initial trials [24]. This is a common and probably the fastest approach to finding a possible effective therapy against COVID-19. An AI-based platform helps optimize drug combinations fast and avoids suboptimal clinical treatments, reduced morbidity, and unnecessary patient mortality [25].

Drug discovery is time-consuming and expensive; however, AI such as machine learning (ML) can help shorten the discovery process [26]. Old drugs with activities against FIP (feline infectious peritonitis) coronavirus were identified using AI. More studies are ongoing to confirm their activities against SARSCoV-2 in vivo and in vitro at clinically achievable concentrations and doses. Remdesivir is a drug that shows potential outcomes in compassionate uses [27]. AI methods such as DL help accelerate drug discovery by predicting which available drugs or brand-new drug-like molecules can treat COVID-19[28].

AI can be used in virus research, evolution of drugs and vaccines, services and resources allocation at healthcare centers, and public policy decisions such as patient isolation and quarantine [9]. AI has been applied to areas of drug discovery and vaccine development. This is important for immediate therapy discovery of SARS-COV-2. DL with the automated feature extraction capability can produce accurate models and achieve good results [29].

Prediction of COVID-19, prevention of its spread, and sentiment analysis

Predictions for COVID-19 with DL models, including gated recurrent network (GRU), long short-term memory (LSTM), and bidirectional long short-term memory (Bi-LSTM) were evaluated for time series prediction of confirmed cases, deaths, and recoveries in ten main countries suffered from COVID-19. In most cases, models ranking from the best performance to the lowest is Bi-LSTM, LSTM, GRU. According to enhanced prediction accuracy and demonstrated robustness, Bi-LSTM could be used for pandemic prediction for better management and planning [30].

During the COVID-19 pandemic, AI, Big Data analytics, robotics, block chain technology, and drone technology are increasingly playing a significant role. AI helps disseminate public health education. Virtual healthcare chatbots have been developed in social media platforms to offer guidelines and advice on prevention and protective measures. AI has been utilized to develop "video-bots" in collaboration with hospitals in India. This kind of platform enables people to get information regarding COVID-19 directly from a doctor via the video interface. Singapore government has worked on Facebook-owned platform 'WhatsApp' to distribute updated and accurate information regarding COVID-19. Robotic technology has been used to dispose waste from hospitals and help healthcare professionals and sanitary workers in reducing their risk of exposure to the virus [31].

Chatbots have been deployed in Facebook Messenger. They can be distributed to educate people across the world, reduce panic, and greatly reduce false information spread. Chatbots revolutionize public communication, especially during the COVID-19 pandemic [28]. Public sentiment related to the pandemic were obtained using R statistical software, Coronavirus specific Tweets, and sentiment analysis packages. Understanding public perspectives and sentiment through ML and textual analytics helps policy makers to take care of public needs and develop communication strategies with the consideration of specific sentiment [32].

Summary of AI in emerging diseases and COVID-19

AI based robots help fight COVID-19. The robots help minimize duties of healthcare workers in hospitals. 5G network combined with AI helps perform remote video consultations due to its high bandwidth and low latency, making an early diagnosis and treatment more efficient [9,26] [Table 3] shows some applications of AI in emerging diseases [Table 4] [33] summarizes main applications of AI technologies in combating the COVID-19 pandemic.

Applications	Description
Structural analysis	Characterization of the structures of emerging diseases such as COVID-19 and key functional sites.
Disease prediction	AI such as ML enables the prediction of next-generation viral mutations.
Drug repurposing	Mining datasets of existing drugs is helpful for insights into disease treatment, which facilitates efficient drug repurposing.

Novel drug development	Rapid processing allows for high efficiency across the entire pharmaceutical lifecycle, which speeds up drug development.

Table 3: Some applications of AI in emerging diseases.

Main applications	Description
Workload reduction	Facilitate early diagnosis and treatment, address potential challenges, offers trainings, and therefore reduce the workload of doctors and health care workers.
Early detection and diagnosis of infection	Quickly analyze irregular symptoms and alarm healthcare authorities and patients; help diagnose infected cases utilizing MRI, CT, etc.
Projection of cases and mortality	Identify the most vulnerable countries, regions, and people; predict numbers of infected cases and death in a region.
Contact tracing of individuals	Perform the contact tracing of individuals and identify clusters and 'hot spots' of COVID-19.
Prevention of the disease	Provide updated information based on real-time data analytics and help prevent the disease.
Monitoring treatment	Build an intelligent platform for monitoring the treatment and predicting of the spread of COVID-19.
Development of drugs and vaccines	Find effective drugs for COVID-19 patients; speed up drug and vaccination development, drug testing, and clinical trials.

Table 4: Main applications of AI in COVID-19.

Challenges of AI applications in COVID-19

An AI-based smartphone app has been developed to track the spread of COVID-19. AI-based smartphone technologies help contact tracing. However, there are challenges for AI in the accuracy of prediction and diagnosis [34]. A lack of data in the early stage of the COVID-19 outbreak resulted in its spread across the world within a few months. In some countries, people have a low level of trust in their governments. Gaining trust and data collection during the pandemic is significant. ML usually works well with defined cases with large training datasets. This leads to slow adaptability of ML in the new and fast-changing COVID-19 pandemic [35].

Although AI techniques are helpful in diagnosing COVID-19, choosing a suitable AI method that produces accurate results is a challenge. Some AI methods suffer from low accuracy and computational efficiency [36]. Three stages of AI (AI input, AI learning, and AI outcome) can contribute to AI-based bias. Algorithmic bias frequently occurs and depends on 1) how the software is developed, designed, and deployed; 2) the integrity, quality, and representativeness of data sources. A barrier to the success of AI is a lack of quality data. Datasets used in AI can be biased, inaccurate, or incomplete. Wide-scale access to relevant big data is significant in many situations [37,38] [Table 5] shows some AI applications with the potential, challenges as well as future prospect in diagnosis, treatment, implementation, etc. regarding COVID-19.

Applications	Description	Challenges	Future prospect
Chatbot	An interactive communication platform between a doctor and a patient, helping to diagnose according to symptoms.	Training a bot with suitable datasets and accuracy in the diagnosis of diseases or conditions of patients	Chatbot technologies will be available through virtual assistants, e.g., Google assistant, Siri, and Alexa.
Non-interpretive utilization of AI in radiology	Image generation and quality control, improving the radiology workflow, research, and applications.	Only a few usable techniques in the clinical practice.	Any improvement in this application will impact health care facilities directly.
Image analysis	Automatic analysis of images (e.g., radiology) with AI in health care	Major legal and ethical issues in health care	Clinicians are required to work closely with the research and development community of AI.
Privacy and security	Privacy protection and data security satisfy all stakeholders (e.g., patients and caregivers) in healthcare.	Detect insecurity cases in handling various healthcare data, encrypting the data, and implementing digital approaches.	Unauthorized access prevention for the security of electronic health record (HER) systems

Table 5: Some potential AI applications with challenges and future prospect.

BIG DATA WITH AI IN FIGHTING COVID-19

Big data in mitigating the risk of COVID-19

Big data technologies can be used to store and analyze pharmaceutical data, EMR, and other medical data [9]. Big data analytics help speed up drug repurposing and discovery. Public health policy making can be improved through model simulations and big data analytics [39]. A multinational collaboration, the Coronavirus Pandemic Epidemiology (COPE) Consortium, was established. It was comprised of leading investigators from some large clinical and epidemiological cohort studies. It brings together a multidisciplinary team of scientists with expertise in translational epidemiology and big data research to study COVID-19 in a diverse patient population [40].

Big data analytics helps contact tracing and identify "hot-spots" based on various data sources such as posts with meta-data and tags on social media. It also facilitates to detect confirmed or suspected COVID-19 cases using social media search indexes that list keywords on a social media site, including symptoms such as fever and cough [34]. South Korea used a system named 'COVID-19 Smart Management System' based on big data to track people with COVID-19 and track individuals with a history of contact with COVID-19 patients [41]. Strategies for the reopening of schools and businesses depend on the collection and utilization of large datasets about people's movements, health, tracing of contact, etc. during the COVID-19 pandemic [42].

Built environment characteristics help to characterize COVID-19 risk at the community level. Research on neighborhood quality and environment characteristics has been conducted based on computer vision and big data resources. Google Street View images were used as a data source for characterizing the built environment. Indicators such as greater physical disorder, walkability (possible increased contact), and greater urban development were related to more COVID-19 cases [43]. Big data enable the geospatial mapping of COVID-19 for pandemic transition analysis; however, there are challenges during the process of data aggregation and knowledge discovery [35].

COVID-19 poses risks to the population and urban sustainability. Analytics with spatial-temporal big urban data are needed for the mitigation of risks. An idea was proposed to analyze the spatial-temporal potential exposure risk of residents through capturing human behaviors based on spatial-temporal car park availability data. The big data analytics of changes in car mobility behaviors and the resulted potential exposure risks can provide insights to facilitate 1) designing a flexible circuit breaker exit strategy, 2) accurate management through detecting and tracing hotspots on the mobility heat map, and 3) making decisions timely by fitting curves dynamically in various phases of COVID-19 mitigation [44].

Big data combined with AI in fighting COVID-19

This pandemic due to COVID-19 also indicates that there was not enough reactionary collection of big data for a timely reaction to the new disaster. Obtaining a high level of portable and interconnected big data is a challenge due to data silos, privacy regulations, and strained international relations. Necessary protection requirements for legal data affect data use and sharing within and between organizations, which slows the utilization of intelligent automation (IA). More research is required to study a balance between adequate big data supply and IA development without compromising privacy and cybersecurity [45].

Big social media data such as geotagged tweets have been utilized in the studies of human mobility. Big social media data (Twitter), AI, and spatio-temporal analysis have been used to monitor the spread of COVID-19 at various spatial scales for improving situational awareness and risk prediction. A database with optimized spatiotemporal indexing has been developed to store and manage multi-source datasets. The database can be connected to an in-house Hadoop computing cluster for Big Data analytics [46]. AI has been used to investigate COVID-19 transmission, improve the detection rate, seek treatment, develop vaccines, etc. For big data, AI relies on both the availability and reliability of data to complete tasks, including improving early warning tools and preventing or slowing COVID-19 spread through contact tracing and surveillance, diagnosing and detecting the disease, vaccine development, etc. But gaining access to the data is not easy in some situations. Collecting reliable and accurate big data regarding COVID-19 is a challenge [45].

AI integrated with big data helps enhance the effectiveness and efficiency of drug repurposing for COVID-19. But there are challenges due to low data quality, data heterogeneity, and inadequate data sharing between companies in pharmacy, as well as the interpretability and cybersecurity of AI models. Better models of AI for drug repurposing are expected to be resilient to noise and cyberattacks, integrative in disparate information sources and types, and accurate in final outcomes [47]. Also, AI with big data helps discover new medicines for the treatment of COVID-19. AI techniques such as reinforcement learning can be employed to decide a selection for the best clinical outcome. Evaluations of patients according to a single type of data can be skewed; therefore, there is a need to create a multimodal framework of AI with the capability of analyzing various types of data. The utilization of AI may need access to personal or private information. Patient information sharing can bring privacy problems. Therefore, ethical guidelines and laws are necessary for the utilization of both AI and big data [48,34] [Table 6] shows some shortcomings of AI methods and Big Data analytics.

AI methods	Big data analytics
Back-propagation used in ANN can lead to local optimization (failure in global optimization), which affects the computation accuracy.	Challenges in geographical data merging and sharing for a quick case detection of disease infection and the tracing of contacts.

Possibly suffering from over-fitting and under-fitting that result in a poor accuracy.	It is not easy to determine the and reliability and accuracy of posts of social media.

Table 6: Some shortcomings of AI methods and big data analytics.

CONCLUSION

RT-PCR test is a reference method for the diagnosis of COVID-19. CT and X-ray imaging, blood and urine tests, etc. can also be used for diagnosis. AI has promising diagnostic performance in COVID-19 only using small data of chest CT. DL can distinguish COVID-19 from other atypical and viral pneumonia diseases with high accuracy. Ensemble methods should be developed for a better accuracy. AI and blockchain can be integrated with POC diagnostics to perform self-testing of patients in isolation.

Both AI (e.g., DL) and Big Data analytics help speed up drug repurposing, drug discovery, and vaccine development. AI integrated with big data has the potential to find new drugs and enhance the effectiveness and efficiency of drug repurposing for COVID-19. DL models have been used in predictions for COVID-19. Big data analytics helps contact tracing and identify "hot-spots" of COVID-19. Public sentiment analysis based on ML and textual analytics helps to improve decision-making.

Challenges of AI in combating COVID-19 lie in data heterogeneity, insufficient data sharing, and data quality problems such as biased, inaccurate, or incomplete data that affect the accuracy of prediction and diagnosis. The utilization of AI may need access to personal or private information.

Patient information sharing can result in privacy problems. For Big Data analytics, there are challenges such as tracing of contacts, low quality data, and geographical data merging and sharing.

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