Review Article

Artificial intelligence in the diagnosis and management of COVID-19: a narrative review

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Abstract: As per November 2020, there have been over 51.5 million cases of COVID-19 in the world with its mortality rate being close to 7%, causing a major burden on health care systems. Artificial intelligence (AI) is a promising tool, the use of which has been encouraged for the development of an automated diagnosis system for COVID-19 minimising the drawback of limited reverse transcription polymerase chain reaction (RT-PCR) tests. It is a time-saving, cost-effective approach, which is being promoted for reducing the physician burden during the pandemic crisis. For this narrative review, most recent data sources were collected from PubMed and Cochrane Library. Deep Learning is a promising technology for the automated diagnosis of COVID-19 through the use of advanced algorithms that identify hidden patterns on patient radiographs. Machine learning is useful in predicting patient prognosis and biomarker analysis is helpful for customised treatment planning. Infrared thermal scanners, chatbot applications, AI-based decision-making systems and image analysers are some generic contributions of AI assisting in the contactless diagnosis in suspected patients. Overall, deep neural network-based approaches have found to be superior to RT-PCR in diagnosing COVID-19 having a sensitivity of 85.35% and a specificity of 92.18% in the image-intensive diagnosis of pneumonia. In patients with comorbid conditions, telemedicine is a significant contribution of AI for monitoring and diagnosis positive cases through the use of applications such as *My Day for Senior on Alexa Daily Check*. Despite these advantages, the use of AI is only recommended under the guidance of the physician until sufficient clinical trials are not conducted supporting its independent use. Conclusively, the role of AI is prominent in the detection and diagnosis of COVID-19 through the use of technologies such as machine learning, deep learning and deep neural networks. However, its careful use is recommended until suitable clinical trials confirming safety are not conducted.

Keywords: Artificial intelligence (AI); COVID-19; machine learning; telemedicine

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Introduction

Corona virus Disease 2019, or COVID-19, has over 90.9 million confirmed cases as per statistics from 12th January 2021 (1). It is caused by severe acute respiratory syndrome coronavirus-2 (SARS-COV-2), which is a single stranded RNA virus causing respiratory infection in humans (2,3). Compared to the previous strains causing severe acute respiratory syndrome (SARS) and middle eastern respiratory syndrome (MERS) infections, SARS-COV-2 has a much higher rate of infectivity, thereby succeeding to achieve a worldwide spread (1,3). However, it has a significantly lower death rate of 3.63% (as of March 2020)/7% (as of end of April 2020) while that of SARS was 11% and 37% for MERS 37% (3,4).

Rationale for the review

There are several issues faced in the management of COVID-19, which can be met through the involvement of artificial intelligence (AI). COVID-19 presents with pneumonia and flu-like symptoms, which makes it difficult to

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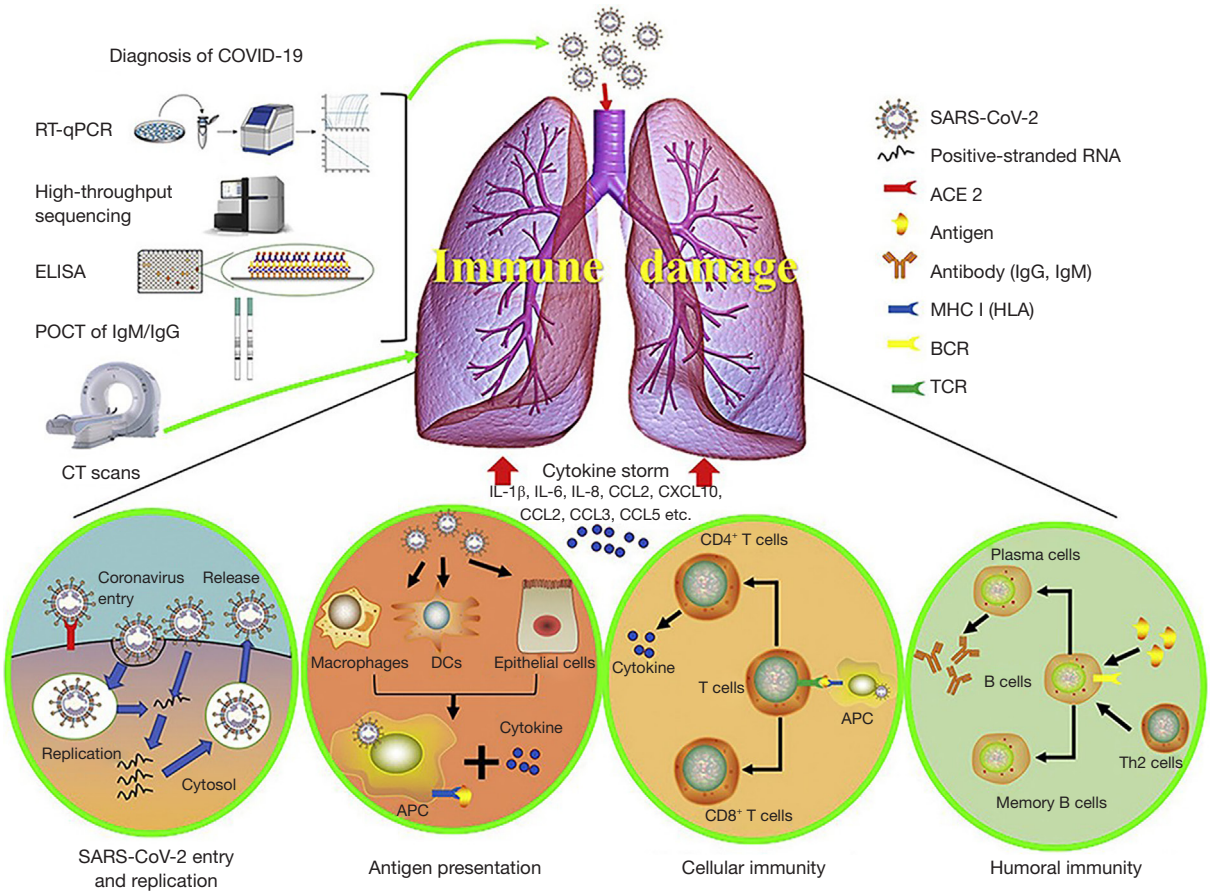

Figure 1 Pathophysiology of the COVID-19 (4). This figure was reproduced with permission from Li X, Geng M, Peng Y, *et al.* [2020] from their manuscript titled "Molecular immune pathogenesis and diagnosis of COVID-19".

differentiate from other types of respiratory infections at an early stage, especially with the lack of large-scale screening programs (5). There is a high risk of community spreads owing to the lack of early diagnosis (refer to *Figure 1* for its pathophysiology) (4,6). With the current levels of spread of COVID-19, it has been recognised that the efforts of health care professionals, alone, are not sufficient in controlling the outbreak, especially when most of the treatments and vaccines are still under the phase of clinical trials therapies (7). The inclusion of AI technologies helps physicians in reducing the challenges faced during the management of COVID-19, including the risk of self-contamination through positive cases, overburdening and limitations with quick decision making in stressful situations (8).

AI refers to the simulation of human intelligence by machines without being actively encoded with additional commands (9). During the pandemic crisis of COVID-19, it is being used for the screening of positive cases, description of predictive and analytical models in decision making, treatment planning as well as prediction of future cases and vaccine development (10). It is noteworthy that the global spread of COVID-19 was predicted by AI platforms such as Bluedot Global before the cases started from China (11). However, while AI is widely used for prediction, its use is limited with respect to diagnosis and treatment planning for COVID-19 in the present scenario. Further, its utilisations with respect to high-risk populations remain unclear.

Objectives

The purpose of this review is to explore the practical applications of AI in COVID-19 including its use in

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Table 1 Summarisation of research methodology of the narrative review

Sources used for the narrative review
PubMed search
Year: 2010–2020
Keywords: COVID-19, artificial intelligence, machine learning, infection
Cochrane Library search
Year: 2010–2020
Keywords: COVID-19, Artificial Intelligence, Systematic Review, Meta-Analysis
Personal Library at the Cleveland Clinic, Abu Dhabi
Personal experience participating in and writing several reviews of the literature in the field of artificial intelligence
Discussion with experts in the field of review of the literature

diagnosis, treatment planning, identification of high-risk cases and prevention. Its main objective is to identify artificial diagnostic tools that can be used in the present pandemic situations in order to streamline hospital procedures and reduce physician load. It also aims to answer the key question about the utilisations of AI for high-risk populations including the elderly, diabetic patients, hypertensive cases, asthmatic patients, pregnant women, cancer patient and post-transplant cases.

We present the following article in accordance with the Narrative Review reporting checklist (available at http://dx.doi.org/10.21037/jmai-20-48).

Methodology

The sources used for the review have been listed under *Table 1*.

No prospective or retrospective data from human subjects has been collected for the purpose of this manuscript. Hence, no informed consent and ethical permissions were needed. The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Results

AI-based diagnosis facilitates early detection of COVID-19, which is one of its most significant advantages (12). In a clinical trial of 1,014 patients in Wuhan, it was found that the using chest CT for diagnosis is more sensitive for the diagnosis of COVID-19 when compared with RT-PCR tests (13). The use of machine learning (ML), trained on the basis of patient data from Wuhan, has been found to have a predictive accuracy of 80% for determining the patient prognosis (13).

Deep learning for the detection of COVID-19

Deep Learning-based predictive method is the most suitable method for diagnosis COVID-19 as well as complications such as pneumonia on the basis of data augmentation of radiographic images (DARI) algorithm and convolutional neural network (14). The DARI algorithm combines a generative adversarial network (GAN) model with generic augmentation techniques for the generation of synthetic radiographic data (14). This synthesised data assists in the scanning of CT images for the detection and monitoring of COVID-19 features on the radiograph (14). DL-based algorithms are efficient in uncovering hidden patterns within patient radiographs that serve as key to diagnosis (15). Anterior-posterior radiographs of the patient are perceived with high accuracy by DL models (96.3%) reducing the possibility of false positive and false negative results (15). In some studies, the specificity and sensitivity of AI technologies has been predicted to be as high as 100% indicating its possibility to minimise the manual interactions required by the radiologist for diagnostic procedures (15,16).

Deep neural network algorithm is of major diagnostic value in positive cases. It is based on real-time object

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detection system through training from X-ray images (17). Deep neural network model has a sensitivity of 85.35%, a specificity of 92.18% and an F1 score value of 87.37%; DarkCovidNet (a model of deep neural network) achieved this result (14,17). This makes it to be superior in comparison with the reverse transcription polymerase chain reaction (RT-PCR) test, which is conventionally used in the diagnosis of COVID-19 cases (sensitivity of 60% to 70%) (17,18). Some evidence has highlighted that AI-based models making the use of deep neural networks have comparable efficiency to radiologists in the process of diagnosis (19). The elaborate analysis of X-ray and CT parameters by AI has the potential to identify minute changes which could possibly be ignored by the physician (18). However, their use without the supervision of radiologists is currently not recommended because of the absence of clinical trials on COVID-positive patients.

Deep learning platforms also help in differentiating COVID-19 from the symptoms of flu, in cases where it is non-distinguishable by physicians (20). This is particularly helpful in low-income countries where a large-scale RT-PCR may not be economically feasible (20). Its sensitivity for differentiating COVID-19 from community—acquired pneumonia is 87% and its specificity is 95% (18). Thus, AI-based diagnosis of COVID-19 under the supervision of the physician is said to be time-saving, economical and is ascertained to reduce the burden faced by health care professionals as well as overcome the drawback of lowering number of RT-PCR test kits (21).

Discussion

AI is an efficient technique, which enables faster diagnosis of infectious diseases, their early prediction, large scale screening and efficient decision making (10). It also assists in public reporting by tracking high-risk individuals from the contact history of the identified positive cases (8,10). The applications of different AI tools in COVID-19 have been elaborated below.

Definitions and overview of AI tools used during COVID-19

Machine learning for predicting high-risk cases

ML is utilised for the integration of statistical models for the discovery of new knowledge from the data (22). It is used for developing prognostic algorithms for the prediction of the risk of mortality in COVID-19 positive cases. The use of ML helps to forecast the patients who will be most severely affected by COVID-19 enabling efficient treatment planning, early intensive care support and resource allocation for high-risk cases (23,24).

Deep learning and neural network for automated diagnosis

Deep learning involves the resolution of complex algorithms from unstructured, varied, and interconnected data (22). It assists in the automated diagnosis of COVID-19 for favouring early patient management (17). ResNet50 model with Support Vector Model classifier makes the use of X-rays to provide the best diagnostic results (17).

Neural networks refer to the development of tailored solutions from the study of patient's data (22). They are used in the diagnosis of COVID-19 from the analysis of chest radiography images of patients (17). Neural networks also have a use in efficient patient monitoring and in providing regular updates of the case to the multi-disciplinary teams (19).

AI in the prediction of COVID-19 positive cases

AI and the use of infrared thermography are useful tools in the early diagnosis of COVID-19 (19,25). Fever is the most common early symptom reported in almost 83% of the patients as depicted by a recent meta-analysis (25). With the advancement of AI technologies, thermal scanners can be installed as mobile phone applications making it easier to screen large populations (26). This neural network-based contactless technology is used for self-screening as well as population-based screening before large gatherings, community-based activities and even at the point of entry to hospitals, restaurants or treatment centres in times of COVID-19 (26). Some facial-recognition companies such as Sense Time have integrated thermal imaging-based facial recognition of fever, which can be installed at entry points of public places for automated screening (25,26). This advances the social distancing protocol and minimises the need for human resource involvement. Other than thermal scanners, acoustic AI technologies are used for differentiating healthy patients from positive cases through the sound of their cough; however, the data on this is limited at the current stage (26).

Large-scale screening with AI technologies helps in building of the government database for ensuring timely tracking and notification of patient's information to the

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Table 2 WHO recommendations for treatment of COVID-19 (5)

Recommendations for management of COVID-19 (5)
The current WHO-prescribed treatment protocol for COVID-19 involves the use of continuous positive airway pressure method for pre-oxygenation, lower tidal volumes and lower inspiratory pressures for mechanical ventilation and PEEP therapy
In case of patient deterioration, mechanical ventilation is recommended
Medical management comprises the use of ritonavir (400 mg/100 mg 12 hourly), chloroquine/hydroxycholroquine (500 mg/200 mg 12 hourly). The use of any non-selective antibiotics and corticosteroids is not recommended. However, azithromycin has demonstrated efficiency in some clinical trials and is used selectively

relevant authorities (20). Through this sharing of data, AI has been efficiently trained for taking up bigger roles in the management of the pandemic including public health assistance through Chatbot applications, which are already being used in a large number of countries (20).

AI in the diagnosis of COVID-19

The most notable application of AI in the COVID-19 crisis is its role in diagnosis. AI tools quickly identify irregular patient symptoms or 'red flags' among hospitalized cases thereby instituting faster decision making in positive cases (10). Approximately, 15% of positive patients progress to have severe pneumonia, of which, 5% develop serious complications such as acute respiratory distress syndrome, sepsis, and multiple organ failure (5,18). The utilisation of AI technologies in this context helps to foresee patient deteriorations and advance decision-making processes (18).

AI in the treatment of COVID-19

Overview of treatment for COVID-19

Currently, the treatment offered against COVID-19 is only supportive aimed at preventing the worsening of patient symptoms due to the advancement of infection (5). The mainstay of clinical treatment involves symptomatic management; oxygen therapy and mechanical ventilation in case of respiratory failure (5) (refer to *Table 2* for information on the current WHO prescribed treatment protocol). For patients with septic shock, hemodynamic therapy may be required (27,28).

Role of AI in the treatment of COVID-19

The current applications of AI in treatment include its role in telemedicine and decision making through the analysis of EHR and trial data (18). AI tools such as logistic regression models can be used for determining patient prognosis in cases of sepsis through the identification of biomarkers such as C-reactive protein and procalcitonin (28). This can help physicians in planning timely actions to prevent severe patient deterioration (28). By analyzing trial data, AI technologies can help in selecting the most suitable treatment options for the patient thereby enhancing patient outcomes (29). EHR analysis helps in the prediction of signs of clinical deterioration, thus, alarming physicians for planning of emergency management in positive cases (29).

Further, decision tree analysers and artificial neural networks have made it possible to design a real-time alarming system, which can be used during COVID-19 crisis (30). Medical decision support systems also allow the planning of treatment priorities (30).

Since most of these technologies have not been tested on COVID-19 cases, large-scale clinical trials need to be conducted before validating its use in treatment. Until then, AI can be used under close supervision of the physician for treatment planning.

Another role of AI in the management of COVID-19 is in the process of drug repositioning, wherein AI algorithms are used for predicting the protein structure of the virus, based on which, treatment protocols are designed with the help of biomedical graphs (31). Generated network complex, deep neural networks, conditional latent space sampling and fingerprint-based deep neural networks are used for drug discovery (32). They are also used for predicting the properties of the formulated drugs enabling their practical utilisation (32). Using similar techniques, AI technologies are also witnessing their role in the formulation of vaccine against COVID-19, which may conclude its spread (26).

Telemedicine during COVID-19

Telemedicine helps in providing treatment support to patients with mild discomforting symptoms due to conditions

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other than COVID-19 for minimizing their exposure to the SARS-COV-2 virus (21). It has been ascertained that patients with comorbid conditions are more likely to make the use of telemedicine practices rather than turning to a new practitioner in times of COVID-19 crisis (26). So, with the help of proper training of both physicians and patients, telemedicine can be used for the remote management of comorbid conditions (33). For patients living in remote areas, it can also be used for identifying patients at risk of COVID-19 through symptom-based analysis, following which, an RT-PCR can be prescribed (33). Through the involvement of interdisciplinary team in telemedicine practices, diagnosed positive cases can then be safely escorted to hospital settings reducing their interactions with health care staff members and other patients (33). The use of AI in this process ensures that possible COVID-positive patients are directly admitted to specialized wards, which minimizes the risk of exposure among non-COVID hospitalized patients (10).

Assessments to be made via telemedicine include regular checking of body temperature, calculation of respiratory rates and patterns, presence of cold/cough/fatigue/flu-like symptoms, generalized signs of illness and lymphadenopathy, which can be observed through patient-directed palpation of cervical lymph nodes while making the use of video conferencing tools (33).

Digital technologies are also used in the surveillance, control and management of patients living in remote areas during COVID-19 crisis. Innovative measures such as the use of drones are presently being employed for the transportation of medical samples for testing from remote areas (26). They are also used for commuting medical essentials for symptom-based management in these areas. Further, the use of surveillance drones helps in pointing out individuals who are not following lockdown/social isolation measures who are then followed up (26). Telemedicine is also helpful for remote management of high-risk population/individuals with comorbid conditions (refer to *Table 3*) (34-58).

Rewards and limitations of the use of AI in the COVID-19 situation

AI helps in providing an early response to the pandemic by enabling efficient patient monitoring, screening and decision making for the prevention of large-scale community spread of COVID-19 (10). One of the major rewards of the use of AI in the management of the COVID-19 is that it helps in reducing the burden of health

Table 3 Applications of artificial intelligence for managing special cases during COVID-19 (34-58)

Type of population	Issues faced during COVID-19 pandemic	Applications of AI for management
Elderly patients	Above the age of 60 years, the risk of comorbid conditions such as hypertension, diabetes and cardiovascular disorders is higher (3). This raises the risk of severe manifestation of COVID-19 symptoms due to compromised immune status (34)	AI technologies predict the risk of disease advancement in elderly patients who have been diagnosed with COVID-19 through the identification of warning signs. This can be made possible through image-intensive analysis of X-ray, CT and MRI data, which helps in early detection and timely management (19)
	Elderly patients have higher pneumonia severity index, greater risk of infections involving multiple lobes, and consequently, larger ICU admission rates and mortality (3)	AI-based surveillance models help in monitoring the emergence of respiratory tract infections thereby alleviating the risk of mortality due to pneumonia (3). Specific AI-based applications have been dedicated to the support of elderly COVID-19 patients. My Day for Senior on Alexa Daily Check focuses on virtual screening of elderly patients with COVID-19 symptoms (26). This reduces the need for repeated hospital visits and lab-based analysis minimizing their risk of exposure (33)
		Telemedicine is recommended to be continued even after the management of this pandemic situation in elderly populations to allow a smooth transition to their usual lifestyles (34)

Table 3 (*continued*)

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Table 3 (*continued*)

Type of population	Issues faced during COVID-19 pandemic	Applications of AI for management
Asthmatic patients	The symptoms of COVID-19 are similar to asthmatic exacerbation, which hinders early diagnosis of COVID-19 in most asthmatic cases (35)	The use of modern telemonitoring systems can be made for identifying serious patient deterioration symptoms based on the use of predictive AI models (36)
	Asthmatic patients are at a greater risk of pneumonia/acute respiratory distress syndrome due to COVI-19 (36,37)	Machine Learning and Support Vector Machine can be used to predict future episodes of asthma exacerbation (38). This analysis is based on data collected from EHR sources, social media feeds of the patient and other relevant platforms. Although artificial intelligence is not vigorously used in the treatment/diagnosis of COVID-19 in asthmatic cases, home-based tele-monitoring systems, that have shown to have an accuracy of 0.80, a sensitivity of 0.84 and a specificity of 0.80, are used by pulmonologists for remote patient monitoring (38). Another monitoring model involving the use of neural network has an accuracy of approximately 100% in diagnosing the cases of asthma (38). So, it can be used in making differential diagnosis between COVID-19 and asthma after sufficient training and clinical trials (36). For the treatment of asthma during the times of lockdown, the same treatment protocol can be followed in patients without the discontinuation of any drugs including inhaled corticosteroids lest it results in exacerbation of symptoms requiring an ED visit (39,40). Additionally, machine learning can be for identifying the known allergens of the patient, which can then be avoided (40)
Diabetic patients	Diabetes Mellitus is one of the chronic conditions, which has been cautioned to increase the risk of COVID-19 susceptibility and mortality (41)	Artificially intelligent technologies are of pronounced use in the management diabetic patients. Predictive population risk stratification tools can be used for assessing high-risk patients who are more likely to be hospitalized due to poor diabetic control and suffer from complications (42). Following this, clinical decision support making tools can be used for deciding the course of action. Convolutional neural networks can also be used for automated retinal screening for the diagnosis of diabetic retinopathy (22). If critical support is needed, tools such as random forests can be used for decision making related to treatment procedures (22,42)
		The use of artificial intelligence will fasten the process of hospital procedures minimizing the exposure time of diabetic patients. After their hospital discharge, support vector machines can be used for self-management practices, and they can also be supported by their physicians with the help of telemedicine (22)
		Through the practice of Telemedicine, AI can be used for health education and counselling such as proper dose of insulin and treatment compliance, which are important parameters for glycemic control in diabetic patients (22,42). This will reduce their need for frequent hospital visits due to the avoidance of side effects such as diabetic ketoacidosis or hypoglycemia (12,42)

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Table 3 (*continued*)

Type of population	Issues faced during COVID-19 pandemic	Applications of AI for management
Hypertension	Hypertension is another comorbidity, which has been linked with severe manifestation of Corona virus disease (43). However, there are no clear guidelines on the management of hypertension during the pandemic. The use of ACE inhibitors has been said to facilitate the binding of SARS-COV-2 thereby increasing the risk of COVID-19 in hypertensive patients (44). However, a larger consensus has been on the continuation of ACE inhibitor therapy and rennin-angiotensin system blockers even in the times of COVID-19 to prevent (45)	In the absence of clear consensus guidelines, a careful analysis of risks and benefits is required in all patients of hypertension for selecting suitable treatment agents that reduce their risk of COVID-19. Such high levels of critical thinking can be supported by AI platforms such as deep learning, which work by analysing the patient's data (43) Further, telemedicine can be safely used for patient education and disease prevention in hypertensive cases. Dietary and lifestyle changes can be prescribed to patients with the help of telemedicine, which may be sufficient for the management of mild hypertensives and borderline cases (43,44). Another clear use of telemedicine in this scenario is remote monitoring of patients and early initiation of treatment preventing any complications (46). Specialized applications can be used for recording their data, which can alarm the physician about patient's high blood pressure in time (46)
Cancer patients	Cancer patients, especially those who have recently received chemotherapy/radiotherapy are at an elevated risk of COVID-19 because of an immunocompromised state (47)	AI-based models can be helpful in determining the signs of clinical deterioration in COVID-positive cancer patients from the analysis of epidemiological and EHR data as well as in radiographic analysis for early patient management (47-49)
	Pneumonia associated with Coronavirus disease has a mortality rate of 24% in cancer patients while it is only 3% in other positive cases (48)	AI models can also be used for selecting the best treatment regimens for the patients. Currently, network proximity analyses of drug targets and host-virus interactions have found that of sirolimus plus dactinomycin, mercaptopurine plus melatonin, and toremifene plus emodin are effective in the treatment of COVID-19 in cancer cases (47). In all cancer patients, it has been recommended to utilize Telemedicine platforms for prescription and refilling, while it is generally recommended to avoid treatment-free remission in this state (47-49)
	33% of COVID-positive cancer patients have severe complications like acute respiratory distress syndrome, acute renal failure, acute respiratory injury and septic shock other than having severe pneumonia (49)	Since AI models have not yet been trained for the identification of uncharacteristic findings, its application in diagnosis must be strictly governed by practitioners and drug selection must be based on patient's profiling. Until then, telemedicine can be used for prescribing preventive protocols such as diet/exercise regimen for the improvement of immune function as well as treatment prescription (50). For cardio-oncologic patients, an efficient cardio-oncologic team can govern telemedicine practices (51)
	Cancer patients may have irregular COVID-19 presentation such as atypical radiographic features showing irregular opacities (50). They may also have varied response to standard treatment regimen	

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Table 3 (*continued*)

Type of population	Issues faced during COVID-19 pandemic	Applications of AI for management
Patients who have received organ transplantations	Transplant patients are at a higher risk of COVID-19 because of chronic immunosuppression and the presence of comorbid conditions (52). Independent studies have outlined a case-mortality rate as high as 10%, which is much larger than that of the general population (53). This indicates the need for an early diagnosis and close monitoring of all transplant cases	Telemedicine can reduce the need for hospital visits by offering massive potential for patient education for the prevention of COVID-19. Telemedicine has already evidenced its potential for offering safe and effective advice to patients who have undergone liver transplant while minimizing their risks of exposure during travelling (54)
	In transplant cases, the presentation of COVID-19 may be different from the general population. A lower degree of fever is initially observed, which is followed by a much more rapid clinical deterioration (52)	Another potential for the application of artificial intelligence is in the remote tracking of patient's signs and symptoms through the use of chatbot applications, which will have customized features of presentation of transplant cases (54,55). This will enable an early diagnosis and more efficient patient management although such platforms are not currently available
		Tele-prescriptions, especially in transplant cases can only be made in cases where the patient's symptoms are mild enough to be managed through its use (55)
		In acute/emergent cases, telemedicine must be strictly avoided, and an inpatient consultation must be planned immediately (55)
Pregnant ladies	It has been identified that pregnant women are more susceptible to COVID-19 infection than non-pregnant women because of anatomical and reproductive changes during pregnancy, which affects their individual immunity (56)	Artificial intelligence can help in the selection of the most suitable treatment agents through the analysis of trial data during pregnancy, which will be safe for both the mother and the foetus (57,58). Although limited treatment agents have been completely approved for use in the treatment of COVID-19 in pregnant women, some safety options have been safety tested with the help of AI models, and can be considered for use in pregnant women. These include chloroquine, metformin, statins, lobinavir/ritonavir and glycyrrhizic acid (56). However, practitioners must closely consider the benefits versus risks of each treatment and prescribe these drugs with careful precaution and remote monitoring (57). Wherever possible, the use of corticosteroids must be avoided (57)
	The SARS-COV-2 receptor is increased during pregnancy, so, the risk of infection through aerosols and infected droplets is elevated (56)	Telemedicine can facilitate the development of personalized treatment protocols for pregnant women during COVID-19 such as regular temperature checks and self-monitoring practices under the physician's supervision (56)

AI, artificial intelligence.

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care professionals by managing the patient flow (9). Second advantage is that its practicable algorithms such as modified Susceptible-Exposed-Infectious-Removed (SIER) models help in providing informations about the epidemic peaks and sizes thereby helping individuals to take necessary precautions in time (59).

Well-trained AI models are also useful in providing insights into the disease patterns, which are not entirely understood by practitioners so far (32). One useful discovery made with the help of deep learning algorithms is that patients may continue to spread the disease even after their efficient recovery because diagnostic tests were found to be positive 5 to 13 days after the treatment (17). This discerns that suitable isolation and quarantine protocols must be followed even after successful treatment and recovery of the patient. Overall, the use of AI helps in enhancing patient safety due to early identification of complications and their logical management (24).

Despite these benefits, AI has some limitations, which is why its applications during the COVID-19 crisis have been limited. One of the major limitations is the lack of clinical trials to demonstrate the safety of use of AI in COVID-positive cases. This confines its use in treatment-related roles; however, it can be safely implemented in the form of telemedicine practices following appropriate national and international guidelines on their pragmatic use (refer to *Table 3*). There is also lack of training and input models, which are essential for the efficient functioning of superior AI systems such as big data analytics (45).

Summary

In the absence of supportive clinical trial data, AI has a limited role during the COVID-19 crisis. It can be used for patient education, thermal screening and early detection of symptoms through chatbot applications. AI can also be used for the remote management of mild symptoms in patients with comorbid conditions through the implementation of telemedicine in practice. For a bigger role such as in treatment planning/diagnosis, physician's supervision is strictly recommended.

Limitations of the review

This narrative review is an early attempt at evaluating the applications of AI during the virulent spread of COVID-19. The quality of research evidence collected for our review is not sufficient to make a strong recommendation since majority of the findings have been gathered from grade III or grade V resources in the absence of randomized clinical trials encompassing the use of AI technologies on COVID-19 patients. With the current lack of clinical trial data and deficiency of clear national and international guidelines regarding the utilization of AI during COVID-19, we do not intend to recommend its applications at our discretion. However, our review provides solid directions for future research.

Directions for future research

Future clinical trials must focus on the comparison of AI-based automated diagnosis of pneumonia in COVID-19 patients with that of radiologists to expand its role in inpatient monitoring. Safety of telemonitoring in critical cases such as patients on active chemotherapy regimen must also be examined. Along with this, future research must elaborate how AI can be used as a prominent tool for managing patient flow in the times of the pandemic.

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Conflicts of Interest: The author has completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jmai-20-48). The author has no conflicts of interest to declare.

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