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Research Article

ARTIFICIAL INTELLIGENCE TECHNIQUES IN THE FIGHT AGAINST COVID-19

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Abstract

The COVID-19 pandemic has caused significant harm to humanity in recent years. However, there is hope that artificial intelligence (AI) technology can help combat emerging diseases. AI-based generative models can combine datasets to develop drugs for exploring new medical compounds. Deep-learning generative models and molecular modeling tools have been used to identify an effective ligand that terminates the operation of COVID-19 major protease. Additionally, AI can accurately detect disease infections through X-ray, MRI, and CT scans, which is more reliable than the RT-PCR method. Physicians can use an automated deep learning-based application to obtain a thorough and informative report to aid in patient diagnosis. Machine learning and AI applications can help governments and medical experts respond more effectively to pandemics or patients requiring urgent medical attention. In a pandemic such as COVID-19, it is crucial to make rapid and precise clinical decisions to determine the severity of diseases. Although AI technology presents promising advantages, further research is necessary to make it faster and more accurate in providing reliable information.

Keywords: COVID-19, AI-based generative model, Drug development, Diagnosis, Forecasting.

INTRODUCTION

On December 31, 2019, the Wuhan Municipal Health Commission in China reported several cases of pneumonia in Wuhan, Hubei Province. After investigation, a new coronavirus was identified. Today, as of August 13, 2023, more than 769 million confirmed cases and over 6.9 million deaths have been recorded globally, proving that COVID-19 has caused significant harm to humanity (WHO, 2023). Likewise, infectious diseases have significantly impacted human life throughout history. They have challenged healthcare systems and affected societies globally, with new emerging infectious diseases continually. The COVID-19 pandemic has brought attention to the severe consequences of infectious diseases on human health and society and the importance of changing our approach to managing infectious diseases (Jones *et al.,* 2020). To effectively manage and control such diseases, we need a comprehensive strategy that includes early detection, development of effective vaccines and drugs, and forecasting of the infectious status of COVID-19. Many people are interested in using artificial intelligence, machine learning, deep learning, and generative AI to manage human diseases (Theodosiou *et al.,* 2023). AI can be helpful in laboratory diagnostics, clinical imaging analysis, clinical decision support systems, and controlling public health epidemics like COVID-19 (Theodosiou *et al.,* 2023). In 2019 the US Food and Drug Administration (FDA) approved Clever Culture Systems' APAS Compact as a Class II Medical Device for laboratory and imaging diagnostics. This automated plate assessment system is the first AI-based clinical microbiology system (Brenton *et al.,* 2020). Additionally, Dascena, a US-based company, conducted a prospective open-label multi-center research between 2017 and 2018 involving 17,758 adult patients at nine hospitals. Their goal was to promote early sepsis detection for clinical decision support. After applying the ML algorithm, there was a clinical improvement for at least one month compared to the time before installation in 2017.

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Dascena has also tested an ML system for predicting the need for invasive ventilation in COVID-19 infection (McCoy *et al.,* 2017). The use of AI can be beneficial in monitoring the outbreak of infectious diseases, identifying potential risks, and tracking the movements of individuals for preparedness purposes (Keshavamurthy *et al.,* 2022). For instance, systems such as Health Map analyze information from online news sources and expert-reviewed platforms, like ProMED, to provide alerts about epidemics on a global scale. During the COVID-19 pandemic, machine learning has been utilized to classify genomics and map lineages quickly and efficiently. This has aided our comprehension of outbreak epidemiology and investigation into the virus's potential zoonotic sources. The ZOE COVID Study collected data on COVID-19 symptoms from 2.6 million individuals through a smartphone application. This information was utilized to forecast possible infections and provide public health data on the progression of illness and the effectiveness of vaccinations (Menni *et al.,* 2020). In the review, we summarizedessential strategies that can help manage and control the impact of COVID-19 on human health and society. Specifically, we focused on the significance of AI-based technologies in anti-COVID drug discovery, diagnosis, and COVID-19 prediction and forecasting.

MAIN TEXT

AI-based drug discovery for anti-COVID-19

Scientists develop a training dataset comprising established drugs to explore possible new compounds for pharmaceuticals. The dataset is then fed into an AI-based generative model, which learns the molecular structure of compounds suitable for medical use (Wang *et al.,* 2021). The model uses techniques like VAE (Variational Auto-Encoder), RNN (Recurrent Neural Network), and GAN (Generative Adversarial Network) to create new potential drugs (Wang *et al.,* 2021). A recent study utilized a deep learning technique to screen 2,635 FDA-approved medications and 1,062 active components from traditional Chinese medicine in search of possible therapeutic candidates for treating COVID-19 (Yao *et al.,* 2023). The aim was to target the virus invasion mechanism in host cells, and the best drugs were confirmed to interact with host receptors or viral spike proteins through molecular docking. Yao *et al.* found several promising therapeutic candidates, including Fostamatinib, Linagliptin, Lysergol, and Sophoridine. These candidates were tested on a COVID-19pseudovirus system, inhibiting the virus from entering human lung cells, even at a nanomolar scale (Yao *et al.,* 2023). This study demonstrated the potential of using deep learning-based drug repositioning for antiviral medicines and provides valuable drug candidates for treating COVID-19 (Yao *et al.,* 2023). Artificial intelligence may benefit drug development for emerging infectious diseases such as COVID-19. Research groups found small molecule substances that can inhibit the SARS-CoV-2 main protease, a key target for drug development in regulating viral replication and transcription (Andrianov *et al.,* 2023; Zhang *et al.,* 2023). In 2023, Andrianov *et al.* created a library of small-molecule compounds for training using deep-learning generative models and molecular modeling tools (Andrianov *et al.,* 2023). They used a Simplified Molecular-Input Line-Entry System (SMILES) to build potential SARS-CoV-2 Mpro ligands and trained neural networks to create multiple possible SARS-CoV-2 Mpro ligands. Then, the most effective therapeutic candidates against SARS-CoV-2 Mprowere identified using molecular docking, molecular dynamics simulations, and binding free energy calculations (Andrianov *et al.,* 2023). Furthermore, a data augmentation strategy was employed in this study to screen for potential inhibitors of SARS-CoV-2 Mpro, which outperformed graph convolution neural network, random forest, and Chemprop in improving transfer learning model performance (Zhang *et al.,* 2023). Using *in silico* analytical techniques, 27 compounds were selected for experimental validation of their anti-Mpro activity (Zhang *et al.,* 2023). Among the preferred compounds, gossypol acetic acid and hyperoside showed inhibitory actions against Mpro with IC50 values of 67.6 M and 235.8 M, respectively. The results of this study may offer valuable guidance in identifying potential treatment targets for SARS-CoV-2 and other coronaviruses (Zhang *et al.,* 2023). Utilizing deep learning-based drug repurposing screening and *De novo* drug design for targeting specific mechanisms of antiviral agents provides the development of new potent and broad-spectrum drug candidates for an attractive therapeutic target for anti-COVID-19 agents.

AI-based diagnosis of COVID-19

One of the most commonly used methods for testing COVID-19 is Real-Time Polymerase Chain Reaction (RT-PCR). The method detects viral nucleotides in samples collected from the upper respiratory tract, including nasopharyngeal, oropharyngeal, or nasal swabs (CDC, 2019). However, it is essential to note that RT-PCR may produce false negatives, with a sensitivity that can drop by as much as 70%. This could be due to a range of factors, such as inadequate nucleic acid detection devices, differences in gene region targets, or a low viral load in the patient (Wang *et al.,* 2020). Several reports have shown that deep learning, a form of artificial intelligence, is highly effective in detecting visual features, particularly in medical imaging-based diagnostics like X-rays, MRI, and CT scans (Liu *et al.,* 2019). A recent study on COVID-19 revealed that the sensitivity of CT-based diagnosis is 0.88 AUC score, while that of RT-PCR test kits is 0.59 (Ai *et al.,* 2020). Additionally, another study presented a deep learning framework that scored an AUC of 0.96 for diagnosing individuals with COVID-19 infection, which was verified by RT-PCR (Yousefzadeh *et al.,* 2021).The chest CT scan of a patient infected with COVID-19 shows involvement of multiple lobes, with areas of consolidation and ground-glass opacity. As the disease progresses, these regions can develop into a "crazy-paving" pattern (Shi *et al.,* 2020). The most common image finding in COVID-19 patients is patchy ground-glass opacities and consolidation that appear asymmetrically in both lungs. Other frequently observed patterns include thickening of the interlobular septa, air bronchograms, and crazy paving patterns during the transitional stages of the disease (Shi *et al.,* 2020). In the advanced stage, subpleural parenchymal bands, fibrous stripes, and subpleural resolution are typical patterns (Shi *et al.,* 2020). A deep learning framework, *ai-corona*, can diagnose COVID-19 infection by analyzing chest CT scans (Yousefzadeh *et al.,* 2021). The framework recognized COVID-19 infections in patients and differentiated them from common pneumonia and other non-COVID-19 abnormalities. They suggested that *ai-corona*'s assistance can increase the speed and accuracy of professional diagnosis (Yousefzadeh *et al.,* 2021).

Using deep learning technology, a researcher developed and tested a new tool that can diagnose COVID-19 through chest CT scans (Topff *et al.,* 2023). This tool has a unique feature that identifies infectious lung opacities through segmentation. The researcher created a multi-class classification model using a custom 3D convolutional neural network. The chosen model structure was a UNET-like structure with a Residual Network (ResNet-34) backbone (Topff *et al.,* 2023). When integrated with an automated deep learning-based application, doctors can access a comprehensive and visual report that can help them make informed decisions for COVID-19 patients who are either suspected or confirmed cases (Topff *et al.,* 2023). According to the study results, this application can accurately distinguish COVID-19 from other types of pulmonary infections or no imaging signs of infection (Topff *et al.,* 2023). A group of 20 European institutions has created an application that automatically diagnoses COVID-19 and determines its severity using deep-learning technology (Topff *et al.,* 2023). The application, Imaging COVID-19 AI, is intended to be a valuable resource for clinicians and radiologists during outbreaks when molecular testing is unavailable in remote regions and diagnosis expertise is in high demand (Topff *et al.,* 2023). The Imaging COVID-19 AI simplifies the diagnostic process, saves time, and enhances patient management without incurring substantial expenses (Topff *et al.,* 2023). The researchers are optimistic that this innovative tool will result in a more efficient and prompt emergency response (Topff *et al.,* 2023). Upcoming research will examine how the Imaging COVID-19 AI affects radiologists' diagnostic proficiency and efficacy.

Chest X-rays have been commonly used to diagnose COVID-19 quickly and accurately. However, there is a significant risk of human error, which can be time-consuming (Subramaniam *et al.,* 2023). Fortunately, new AI techniques offer the potential to create accurate and automatic COVID-19 detection systems. A comprehensive review analyzed chest X-ray images to detect COVID-19 infections using successful deep-learning techniques (Subramaniam *et al.,* 2023). The study explored various deep-learning methods that can be utilized to detect COVID-19 through chest X-ray images.

Table 1. Summary of AI-based techniques in COVID-19

Category	Technique	Description	Outcome	Reference
Drug development	VAE, RNN, and GAN techniques	The dataset is fed into an AI-based generative model	Suggestion of new potential drugs	Wang et al., 2022
	Deep-Learning techniques	Targeting the virus's cell entrance mechanism	The best drugs were confirmed	Yao et al., 2023
	Deep-Learning generative models and molecular modeling tools	Providing small molecule substances that can stop Mpro from functioning	Identified the most effective therapeutic candidates against SARS-CoV-2 Mpro	Andrianov et al., 2023
	A data augmentation strategy	Selection of 27 compounds using in silico analytical techniques,	Suggestion of valuable guidance in identifying potential treatments	Zhang et al., 2023
Diagnosis	A deep learning framework, *ai-corona*	Diagnosis of COVID-19 infection by analyzing chest CT scans	*ai-corona*'s assistance can increase the speed and accuracy of professional diagnosis	Yousefzadeh et al., 2021
	A multi-class classification model by a custom 3D convolutional neural network and initiative called Imaging COVID-19 AI	Diagnosis of COVID-19 through chest CT scans by using deep learning technology	Distinguishing COVID-19 from other types of pulmonary infection or un-infection cases.	Topff et al., 2023
	Deep-Learning techniques	A comprehensive review of analyzing the chest X-ray images to detect COVID-19 infections	Suggestion of potential method to create accurate and automatic COVID-19 detection systems	Subramaniam et al., 2023
Prediction	A stacking ensemble with a support vector regression technique	Prediction the total COVID-19 patients in 10 Brazilian states	Improving the short-term forecasting procedure, leading to effective reactions	Yan et al., 2020
	XGBoost model	The model employs a supervised multilayered recursive classifier to analyze clinical and mammographic factor datasets.	90% accuracy rate in predicting and assessing COVID-19 patients	Chimmula et al., 2020
	A prediction model based on data from Johns Hopkins University	Prediction of SARS-CoV-2 outbreak in Canada was expected to end around June 2020	Accurate predictionas new infections decreased quickly	Lalmuanawma et al., 2020
	The wavelet-based predicting model and the autoregressive integrated moving average-based time-series model	Providing short-term projections for various countries (India, United Kingdom, Canada, South Korea, and France)	Assistance to the healthcare professionals and policymakers by serving as an early-warning system	Chakraborty et al., 2020
	The advanced Deep-Learning techniques based on the findings of the Long short-term memory (LSTM) network	Real-time forecasting technology will inform front-line clinical workers before a crisis	Prediction of transmission rate in Canada on a linear trajectory, while the USA saw exponential growth in transmissions.	Chummula et al., 2020

Combining sign detection with output categorization can enhance model performance and forecast accuracy. Extensive research has shown that medical image-based AI diagnostic methods have excellent potential in preventing and controlling COVID-19. However, these systems and technologies face limitations and challenges, such as generalization and robustness, which need to be addressed in future research. To accomplish this, AI-based techniques must be developed to improve the flexibility and generality of deep learning models. This can be achieved by considering the characteristics, differences, and significance of these models in terms of their application direction, image collection, and algorithm enhancement. Additionally, training models using a substantial amount of accurate X-ray and CT image data for COVID-19 detection is crucial. Finally, to improve model accuracy, it is essential to have comprehensive, diverse, validated, and classified lung disease lesion data by experts.

AI-based technique for public health outbreak management

AI technology is making a significant contribution to the fight against COVID-19. The Blue-dot algorithm can detect early warning signs, while an AI-based diagnostic tool developed in Wuhan has an impressive 90% accuracy rate in predicting the survival of COVID-19 patients. The examples demonstrate the crucial role of AI in managing the current pandemic (Dananjayan *et al.,* 2020). AI is also useful for surveillance, contact tracing, pandemic planning, risk stratification, and diagnosis of illnesses severity (Whitelaw *et al.,* 2020).

A comprehensive review of machine learning and artificial intelligence applications for the COVID-19 pandemic is available. In the COVID-19 pandemic, fast and accurate clinical decision is essential to assess the severity of illnesses. A report has introduced a novel XGBoost model, which employs a supervised multilayered recursive classifier to analyze clinical and mammographic factor datasets (Chimmula *et al.,* 2020). Out of the 75 components of clinical and blood test specimens, the most crucial factors are high-sensitivity C-reactive protein, lymphocyte, and lactic dehydrogenase (LDH) (Chimmula *et al.,* 2020). By applying XGBoost, researchers discovered that these three factors had a 90% accuracy rate in predicting and assessing COVID-19 patients based on their severity levels, general, severe, or mortality rate (Chimmula *et al.,* 2020).The high value of a single lactic dehydrogenase (LDH) test was essential in identifying patients who need urgent medical attention, as respiratory illnesses such as pneumonia, bronchitis, and asthma are all linked to LDH levels. A decision rule was used in a forecasting model to quickly predict and identify patients at the highest risk, providing them with intensive care and reducing mortality rates. According to Yan *et al.,* machine learning tools have identified 3 key biomarkers through an XGBoost machine learning-based model: lactic dehydrogenase (LDH), lymphocytes, and high-sensitivity C-reactive protein (hs-CRP) (Yan *et al.,* 2020). These biomarkers accurately predict a patient's mortality more than ten days in advance with over 90% accuracy (Yan *et al.,* 2020). Even slightly elevated LDH levels can help identify high-risk patients. The results suggest a straightforward decision-making process that can prioritize patients and potentially lower the fatality rate through AI machine-learning tools (Yan *et al.,* 2020). Machine learning and AI were used to predict the COVID-19 pandemic. A new model was created using a stacking ensemble with a support vector regression technique, which can predict and forecast the total COVID-19 patients in 10 Brazilian states 1-3 to 6 days in advance (Yan *et al.,* 2020). The model can help improve the short-term forecasting procedure, allowing the government and healthcare professionals to combat the pandemic more effectively (Yan *et al.,* 2020). Using a deep learning algorithm for a long-short-term memory (LSTM) network, a study analyzed Canadian time-series data to identify a critical factor that could predict the trajectory and endpoint of the SARS-CoV-2 pandemic in Canada and worldwide (Chakraborty *et al.,* 2020; Chummula *et al.,* 2020). The prediction model based on data from Johns Hopkins University suggested that the SARS-CoV-2 outbreak in Canada would end in June 2020, and this prediction was deemed accurate as new infections decreased quickly (Lalmuanawma *et al.,* 2020). To demonstrate the effectiveness of the expert system, critical features were highlighted, and a real-time forecasting model was suggested. The model combines the wavelet-based predicting model and the autoregressive integrated moving average-based time-series model (Chakraborty *et al.,* 2020) and can provide short-term projections for various countries, serving as an early-warning system for healthcare professionals and policymakers. The real-time forecasting technology informed front-line clinical workers before a crisis. Canada's public health authorities acted quickly and effectively to reduce human exposure, which helped to keep the transmission rate in Canada on a linear trajectory while the USA saw exponential growth in transmissions. This research was the first to use deep learning techniques to create a transmission model for infectious diseases and predict the severity of COVID-19 in Canada.

CONCLUSION

The impact of COVID-19 has shown us that we need to be prepare to deal with new emerging diseases. AI-based generative model techniques offer valuable solutions to emerging threats through prediction of potential drugs, accurate diagnoses, and prioritize prompt healthcare management. However, AI technology still needs improvement and overcome the limiting the implementing AI-based techniques in practical sites. These challenges include restricted access to data, the requirement for external evaluation of AI models, healthcare professionals' lack of comprehension, interdisciplinary collaboration between clinicians and AI experts, public concerns regarding data collection, privacy, protection of ethical concerns and the bias and transparency of algorithms of AI-based technologies. However, overcoming these obstacles will lead to significant progress in battling COVID-19. Improved AI-based techniques will be crucial in making significant progress against emerging infectious diseases and help alleviating the burden on physicians. AI-powered techniques have the potential to enhance the medical system and complement human intelligence against future pandemics.

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