Disaster Medicine and Public Health Preparedness

www.cambridge.org/dmp

Artificial Intelligence Functionalities During the COVID-19 Pandemic

Milad Ahmadi Marzaleh PhD[1], Mahmoudreza Peyravi PhD[1], Shahrokh Mousavi MD[2], Fatemeh Sarpourian PhD[3], Milad Seyedi BSC[4] and Naseh Shalyari PhD[1]

[1]Department of Health in Disasters and Emergencies, Health Human Resources Research Center, School of Health Management and Information Sciences, Shiraz University of Medical Sciences, Shiraz, Iran; [2]Student Research Committee, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran; [3]Student Research Committee, Department of Health Information Technology, School of Health Management and Information Sciences, Shiraz University of Medical Sciences, Shiraz, Iran and [4]Department of Computer Engineering, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran

Systematic Review

Cite this article: Ahmadi Marzaleh M, Peyravi M, Mousavi S, Sarpourian F, Seyedi M, Shalyari N. Artificial intelligence functionalities during the COVID-19 pandemic. *Disaster Med Public Health Prep*. **17**(e336), 1–8. doi: https://doi.org/10.1017/dmp.2023.3.

Keywords:
artificial intelligence; machine learning; deep learning; neural networks; COVID-19

Corresponding author:
Naseh Shalyari,
Email: naseh.shalyari@gmail.com.

Abstract

Background: The coronavirus disease 2019 (COVID-19) pandemic has led us to use virtual solutions and emerging technologies such as artificial intelligence (AI). Recent studies have clearly demonstrated the role of AI in health care and medical practice; however, a comprehensive review can identify potential yet not fulfilled functionalities of such technologies in pandemics. Therefore, this scoping review study aims at assessing AI functionalities in the COVID-19 pandemic in 2022.

Methods: A systematic search was carried out in PubMed, Cochran Library, Scopus, Science Direct, ProQuest, and Web of Science from 2019 to May 9, 2022. Researchers selected the articles according to the search keywords. Finally, the articles mentioning the functionalities of AI in the COVID-19 pandemic were evaluated. Two investigators performed this process.

Results: Initial search resulted in 9123 articles. After reviewing the title, abstract, and full text of these articles, and applying the inclusion and exclusion criteria, 4 articles were selectd for the final analysis. All 4 were cross-sectional studies. Two studies (50%) were performed in the United States, 1 (25%) in Israel, and 1 (25%) in Saudi Arabia. They covered the functionalities of AI in the prediction, detection, and diagnosis of COVID-19.

Conclusions: To the extent of the researchers' knowledge, this study is the first scoping review that assesses the AI functionalities in the COVID-19 pandemic. Health-care organizations need decision support technologies and evidence-based apparatuses that can perceive, think, and reason not dissimilar to human beings. Potential functionalities of such technologies can be used to predict mortality, detect, screen, and trace current and former patients, analyze health data, prioritize high-risk patients, and better allocate hospital resources in pandemics, and generally in health-care settings.

The new coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV2), was first discovered in December 2019 in Wuhan, China. It has rapidly spread globally. The World Health Organization (WHO) announced the emergence of this new pandemic disease (coronavirus disease 2019 [COVID-19])in March 2020. Its clinical presentations range from asymptomatic infection to mild symptoms or life-threatening diseases.[1] Patients may present weakness, lethargy, posttraumatic stress disorder (PTSD), dementia, physical or functional disabilities, dysphagia, malnutrition, myalgia, arthralgia, and acute respiratory distress syndrome (ARDS), multiple-organ failure, dyspnea on exertion, muscle atrophy, and premature death. These presentations alter the quality of life in patients and complicate and lengthen the recovery process. There are reports of national-level issues arising from prolonged periods of disease and recovery, and on the other hand, lock-down and various precautions that disturb patients' emotional, psychological, physical, and financial welfare in any age group. This has boosted the need for prompt and accessible health care.[2–5] This pandemic has challenged health-care systems globally and has highlighted their responsibility.[1] Due to the unpredictable nature of COVID-19, hospitals may occasionally face high loads of critically ill or complicated patients who need urgent care. To overcome this challenge, one should be able to successfully predict mortality, diagnose, and screen the patients. Furthermore, early detection of admitted patients and efficient management of hospital resources are necessities for patient prioritization.[6]

Thus, global preparedness and response against COVID-19 are paramount.[7] An increased number of cases in this pandemic has driven health-care systems to use new technologies in prediction, diagnosis, treatment, and surveillance such as telemedicine, wearable sensors, digital call tracking, telerehabilitation, active video games, virtual reality, and augmented reality.[7–12] Many of these technologies can be used to advance health-care systems' resources as a response

to increasing demand, while some others permit distance access to clinical experts, eg, telemedicine.[10]

Artificial intelligence (AI), a rapidly growing technology, is used to automatically detect patterns in areas including image processing, natural language processing, analyzing big data, etc.[10] It is a computational software that is capable of perception, thinking, and reasoning. The rapid growth of computational power and storage space, high volumes of data, and the development of advanced algorithms have precipitated significant growth in AI. Applications of AI are implemented in various fields, for example, machine vision; voice recognition; natural language processing; digital pathology; and data analysis.[13] AI approaches have been used to diagnose diseases (eg, malaria and tuberculosis); better understand the nature of epidemiology (eg, Ebola, Chikungunya); predict infectious diseases; control, manage, and interpret diseases; analyze electrocardiograms; select appropriate treatment; summarize patients' clinical information; make clinical decisions; design personal health routines; assess pharmacotherapies; prevent disease; put surveillance; better explain virus transmission patterns[14]; track and estimate the epidemic course; evaluate severity and duration of epidemic; screen; optimize patient care; differentiate the COVID-19 from other diseases; plan and aid policy-makers.[15–17]

For instance, numerous AI systems have been developed addressing initial the COVID-19 detection using clinical data, chest radiography, or computed tomography (CT) -scan, mortality prediction, social media data analysis, assessing the need for assisted ventilation, etc.[6] In the emergency department, these systems have been used to estimate the number of out-patients, triage electronically, predict latent cardiac complications, predict sepsis, make an appropriate diagnosis by means of natural language processing of practitioners' notes, and detect life-threatening conditions automatically in imaging studies, eg, hemorrhage, hydrocephalous, etc.[10] Furthermore, prescreening tools using AI can screen a very large number of the population continuously with little expense, which removes the high cost of quarantine before test results. In other words, capabilities such as high operational utility and swift detection in such technologies help prioritize test cases, especially if asymptomatic.[18]

AI applications in the COVID-19 pandemic have been subject to many investigations. For instance, Laguarta et al.[18] suggested an AI coughing test to detect COVID-19. The researchers developed a speech processing framework that adopted acoustic biomarker feature extraction to make predictions regarding COVID-19. The results showed that AI can be applied as a free, noninvasive, and robust screening tool on a large scale. Carlile et al.[10] used deep learning for the radiographic diagnosis of COVID-19 pneumonia. They revealed that an AI-based approach can be suitably applied as an appropriate clinical tool in the emergency department. The physicians had generally high satisfaction rates. To the best of our knowledge, no comprehensive review study has assessed AI functionalities for different purposes with regard to COVID-19, eg, prediction, identification, screening, surveillance, control, etc. Few review studies have explored its applications in a specific field, such as prediction[1,6] or diagnosis.[10,18] More research can help caregivers, health researchers, policy-makers, and government authorities gain insights into how various AI models can affect prediction, control, and surveillance in COVID-19. It can also demonstrate the applicability of such technologies in scenarios other than pandemics, eg, long-distance patients, chronic illnesses, malignancies, infectious diseases, and disabilities. Therefore, this study was conducted to assess the potential functionalities of AI in the COVID-19 pandemic.

Table 1. Search strategy for AI functionalities in the COVID-19 pandemic

Strategy	Details
1	Artificial Intelligence **OR** AI **OR** computational intelligence **OR** Machine intelligence **OR** computer reasoning **OR** Machine learning **OR** Neural Network **OR** Brain intelligence
2	THE COVID-19 **OR** COVID19 **OR** Severe acute respiratory syndrome coronavirus 2 **OR** Coronavirus **OR** SARS-Cov-2 **OR** New coronavirus **OR** Corona **OR** COVID
3	#1 AND #2

Methods

Databases and Search Strategies

The study protocol was initially registered at PROSPERO[1] under the registration number CRD42022334688. Following that, a brief search in Cochrane Library confirmed that no similar studies had been published. This scoping review was performed following the PRISMA[2] guidelines. The results were filtered through PubMed, Cochran Library, Scopus, Science Direct, ProQuest, and Web of Science from 2019 to May 9, 2022. Gray literature was also searched, including books, websites, conference papers, and theses. Discrete queries were separated by means of the "AND" operator, and synonyms by means of the "OR" operator. The queries were searched for the "Title, Abstract, and Keyword". The search keywords were chosen from the mesh terms in PubMed database. The search strategy is illustrated in Table 1.

Inclusion Criteria

All the review, quantitative, or qualitative studies in English, addressing the research question (ie, "what are the AI functionalities in the COVID-19 pandemic?"), and relevant to the purpose of our study that passed through the peer-review process were included.

Exclusion Criteria

The articles that were in languages other than English, did not have available full-text, did not have the search keywords in all 3 parts of title, abstract, and full-text, or were irrelevant to the objectives and the question of our study were excluded.

Study Selection and Screening

The articles were imported to an EndNote X9 library and duplicates were removed. Two authors separately screened the articles in parallel based on the inclusion and exclusion criteria in 3 steps: 1. the title; 2. the abstract/description; and 3. the full text.

The discrepancies were put to debate and, if needed, concluded by a third author. Citation and publication biases were taken into consideration. Highly cited studies were assessed through the STROBE checklist. After thoroughly studying the final articles, their information was extracted using a summary form (designed by the researchers) in Microsoft Word 2016. The summary form contains fields for title, corresponding author, study objective, study population, study sample, country, date of the study, study design, materials, methods, and results.

[1]International Prospective Register of Systematic Reviews
[2]Preferred Reporting Item for Systematic Reviews and Meta-analyses

https://doi.org/10.1017/dmp.2023.3 Published online by Cambridge University Press

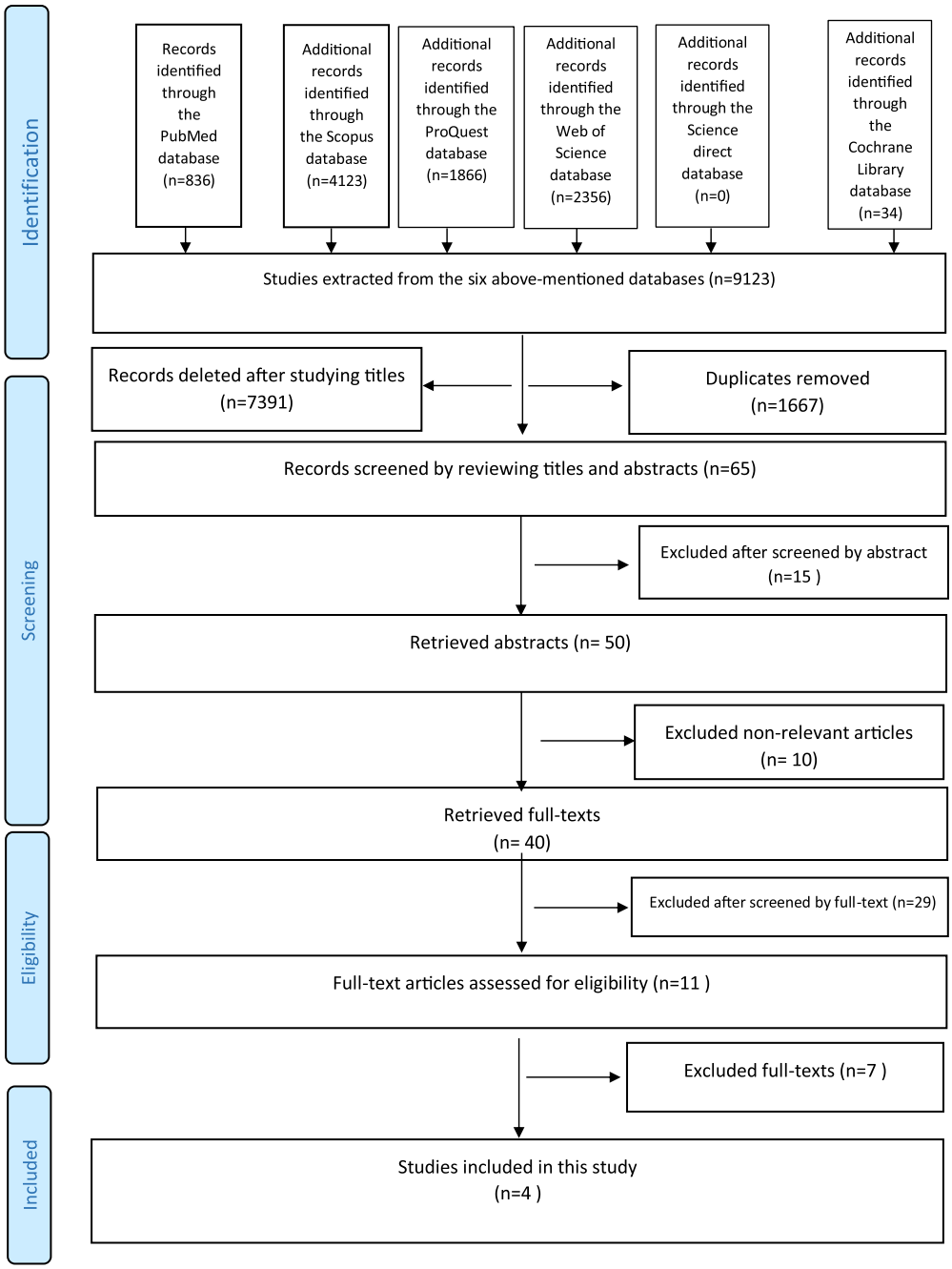

Figure 1. PRISMA flow diagram for the paper screening approach.

Results

The search resulted in 9123 articles. However, 1667 items were removed as they were duplicates. Screening the titles of 7456 articles resulted in removing 7391 (irrelevant objectives). Abstracts of the remaining 65 articles were assessed, and 54 articles were removed (irrelevant objectives). Eventually, the full texts of 11 articles were studied, and 4 were selected. Figure 1 demonstrates the study flow diagram.

Table 2 presents a summary of the functionalities of AI in the COVID-19 pandemic (prediction, detection, and diagnosis) and the most commonly used AI software and environments. Hereby, 2 articles (50%) have applied AI to prediction and detection, 1 article (25%) to prediction, and 1 article (25%) to diagnosis. In addition, 2 articles (50%) used the Python programming language, Keras, and TensorFlow libraries.

The information presented in Table 3 was summarized after a thorough examination of the full texts of these 4 studies.

Discussion

This review study was carried out in 2022 with the aim of assessing the functionalities of AI in the COVID-19 pandemic. The studies of AI functionalities in the COVID-19 pandemic depict satisfactory experiences of health-care staff, improved clinical workflow, effective role of such technologies in clinical decision-making, high-risk patient prioritization, improved hospital resource

https://doi.org/10.1017/dmp.2023.3 Published online by Cambridge University Press

Table 2. Summary of the functionalities of AI and the mostly used software in the COVID-19 pandemic

Functionality	Reference	Ratio
Prediction and detection	[1,6]	50%
Prediction	[18]	25%
Diagnosis	[10]	25%
The mostly used AI software		
Python, Keras, TensorFlow	[6,10]	50%

allocation, decreased laboratory work-up expenses, increased diagnostic precision, community safety, and efficient control and management of the pandemic.[1,6,10,18] Researchers and health-care staff have looked for new technologies to minimize the damage caused by the virus in this pandemic. Proper health care can take great advantage of technologies such as AI to combat new diseases and have a prospective approach. AI can help overcome the pandemic through screening the general public, medical assistance, infection prevention and control alerts and recommendations, surveillance of the pandemic prevalence, and making informed choices. Recent studies have shown the successful application of AI in health care. This technology is potentially capable of planning and improving the treatment course and outcome and is considered an evidence-based medical tool. However, to fully realize the complete potential of this technology in this pandemic requires more time and research.[19–21]

COVID-19 has posed many challenges to patients and health-care systems. This virus has the highest transmission rate compared with other viruses and is fatal to the elderly or some patients with background disorders. Even the countries with the fittest health-care systems have encountered ground-shaking challenges with the most basic accommodations.[22] So, it would be crucial to apply appropriate strategies to impede COVID-19. The existing evidence has shown the advantages of classic approaches for care delivery. However, logistic barriers, economical factors, lack of enough staff and hospital equipment, general circumstances of the pandemic, and lock-downs have disrupted on-time and sufficient care delivery to the critical COVID-19 patients, especially in low- and middle-income countries. New approaches are recommended in such circumstances.[23–26] AI is a relatively new appliance that can swiftly detect COVID-19, help diagnose, monitor treatment, trace physical encounters, predict mortality, help develop new medications and vaccines, and reduce health-care staff burnout.[19] In fact, AI techniques are used to analyze the data on disasters to support better management.[27]

The studies were performed in the United States,[10,18] Israel,[1] and Saudi Arabia.[6] Although novel technologies such as AI have been more welcomed in high-income countries in light of more access to electronic instruments, substantial information technology infrastructure, higher computer literacy, and legislative support,[23,28] international collaboration has assisted its application in upper middle-income countries. Other factors have brought more attention to this technology in upper middle-income countries, including low access to practitioners, health-care service disparities, the low budget allocated to health care, weak coverage of health insurance, untrained health-care staff, transportation challenges, relatively low payrolls, low quality of life, limited opportunities for education, excessive work pressure, etc.[29]

All studies were designed as cross-sectional to predict, detect, or diagnose COVID-19.[1,6,10,18] Two prospective cross-sectional studies in the United States (50%) used AI to predict or diagnose COVID-19.[10,18] AI was used in 2 retrospective cross-sectional studies in Israel and Saudi Arabia, which made up 50% of the studies.[1,6]

Cross-sectional studies evaluate the prevalence of health conditions or diseases and are straightforward, economical widely used. Only 1 cross-sectional study (25%) in 2020 in America used smartphone-based AI to process recorded voices of coughs.[18] Smartphone-based AI technologies permit cost-effective screening of medical conditions, health data analysis, efficient laboratory tests, timely diagnosis of diseases, improved treatment outcomes, analysis of vital signs, etc., using sensors and machine learning algorithms, microprocessors, and high-quality cameras.[17,30] As Sheikh et al. have seen[31] smartphone-based AI reached an accuracy of 89.5% and a specificity of 92.4% in diagnosing diabetic retinopathy. Two cross-sectional studies (50%) in 2020 in the United States and Saudi Arabia used Python, Keras, and TensorFlow to predict, detect, or diagnose COVID-19. These are among the most advanced and flexible open-source software that is used to train and test deep learning models.[6,10]

The AI techniques used in these studies were deep learning and machine learning algorithms. Only 1 (25%) cross-sectional study in Israel used machine learning algorithms to triage critical COVID-19 patients (including neural network, random forest, and classification and regression decision tree). The results indicated that AI can be used as an efficient method to screen, optimize triage, deliver appropriate services to high-risk patients, and better manage the epidemic.[1] Three cross-sectional studies (75%) used deep learning algorithms. Two (50%) of these studies used a convolutional neural network to predict asymptomatic patients and to diagnose COVID-19 pneumonia. The results of these studies showed the relatively high accuracy, sensitivity, and specificity of these algorithms compared with other classical diagnostic methods.[10,18] One study (25%) in Saudi Arabia used explainable AI to detect and predict mortality in COVID-19 patients. It showed an accuracy of more than 95% in clinical decision-making.[6] Machine learning and deep learning techniques take up the relationship between the input and the output of complex processes. Therefore, they are used for decision-making and prediction, although it is not conceivable to interpret these models or justify the resulting prediction or decision. Machine learning algorithms have lower predictive capability compared with deep learning algorithms. Therefore, explainable AI techniques are used to deal with the challenges of machine learning and deep learning algorithms. It permits enhanced, more reliable, and more interpretable decision-making.[1,6,11]

There are numerous studies that have investigated the functionalities of AI for various diseases other than COVID-19. For instance, in a clinical trial by Wu et al.[32] an AI-based system (ENDOANGEl) could detect gastric cancer with an accuracy of 84.7%, a sensitivity of 100%, and a specificity of 84.3% in endoscopic imaging. In addition, a scoping review on AI in rehabilitation showed multiple applications, most commonly through robots and human-machine interaction. Most interventions were delivered in person to groups.[33] Providing AI infrastructure and access to proper databases are important steps for future studies, which should be addressed properly in the forthcoming research. To the best of the researchers' knowledge, this was the first study to examine AI's functionalities in the COVID-19 pandemic. The limitations of the present study were including articles only in English, excluding studies that were not found eligible based on the title and abstract, and the lack of access to the Embase database.

https://doi.org/10.1017/dmp.2023.3 Published online by Cambridge University Press

Table 3. Summary form for the selected studies

No.	Corresponding author/ title/ references	Study objective	Study population	Study sample	Country	Date of the study	Study design	Materials	Methods	Results
1	Jordi Laguarta, Ferran Hueto, and Brian Subirana/ The COVID-19 artificial intelligence diagnosis Using only cough recordings[18].	To develop a natural language processing model using a deep learning algorithm (convolutional neural network) to predict asymptomatic COVID-19 patients, by means of acoustic biomarkers' feature extraction from recorded voices of cough through a cellphone	2660 patients	5320 COVID-19 patients	USA	2020	Cross-sectional, prospective	**Scales:** A set of 10 multiple choice questions approved by MIT COHUES Institutional Review Board **Software**: Libri speech dataset, RAVDESS speech dataset, opensigma.mit.edu website **Hardware**: cellphone	Voice recordings of coughs with varying lengths (3 coughs on average) along with the data from the questionnaire were collected. Dataset balancing was performed. The neural network was trained on 4256 patients and tested on 1064. Data points that did not contain any voice were removed. Only the data on the following patients were used: a diagnosis had been made 7 d before data collection, and symptoms had started more than 20 days beforehand and had lasted ever since.	Artificial intelligence algorithms are capable of detecting asymptomatic COVID-19 positive cases with high sensitivity and specificity. The exported cough differentiation can correctly detect COVID-19 positive cases. Artificial intelligence techniques can be implemented as non-invasive, large-scale, real-time, and location-independent tools to impede COVID-19.
2	Amit Tirosh/ Utilization of machine-learning models to accurately predict the risk for critical COVID-19[1].	To assess the capabilities of machine learning algorithms such as neural networks, random forests, classification and regression decision trees in triaging COVID-19 patients by means of prediction and detection of critical COVID-19 risk using clinical parameters	Critically ill, severely ill, and non- COVID-19 patients whom were admitted to the COVID-19 ward in Sheba medical center between 8th March and 5th April	162 confirmed cases of critically ill the COVID-19	Israel	2020	Cross-sectional, retrospective	**Scales:** APACHE II score SOFA score NEWS 2 score **Software:** Sheba medical datacenter SPSS25 JASP Boot strap **Hardware**: Not mentioned	This study was performed to predict critically ill COVID-19 patients based on their condition on admission. Patients were first evaluated with the medical history, chief complaint, vital signs, complete blood count, kidney and liver function tests, and inflammatory markers. The COVID-19 disease was confirmed by means of reverse transcriptase polymerase chain reaction for ribonucleic acid. Next, they were categorized into critically and severely ill cases. Finally, severely ill cases were excluded.	Machine learning algorithms performed superior to the APACHE II score, SOFA score, or NEWS 2 score regarding the accuracy, sensitivity, specificity, and area under the retriever operating curve for predicting critical COVID-19 cases. These algorithms optimized the use of inflammatory markers, blood count, etc. for predicting critically ill COVID-19 patients. Their efficacy proved useful for accurate COVID-19 risk estimation, screening, triage optimization, resource allocation, prioritization, appropriate care for high-risk patients, and generally improved management of the COVID-19 pandemic.

(*Continued*)

Table 3. (*Continued*)

No.	Corresponding author/ title/ references	Study objective	Study population	Study sample	Country	Date of the study	Study design	Materials	Methods	Results
3	Christian Dameff,/ Deployment of artificial intelligence for radiographic diagnosis of the COVID-19 pneumonia in the emergency department[10].	To use deep-learning artificial intelligence algorithms (convolutional neural network) on chest radiographs to detect the COVID-19 pneumonia	7085 THE COVID-19 cases referred to emergency department (5125 visits and 1960 chest radiographs	1855 cases of the COVID-19 patients	USA	2020	Cross-sectional, prospective	**Scales:** Physician experience questionnaire **Software:** Amazon web services Python 3.5 Keras 2.2 Tensorflow 1.8 IMPAX 6 **Hardware:** Not mentioned	A convolutional neural network was used to interpret chest radiographs in southern California. This algorithm covered the radiographs with heat maps of the possibility of pneumonia along with standard radiographs. Physicians' experiences with the developed software were assessed with regard to ease of use and their effect on clinical decision-making.	86% of physicians agreed strongly or somewhat to use this intervention to diagnose the COVID-19 patients or to predict pandemic peaks and acknowledged its effectiveness in making their workflow easier and clinical decision-making (eg, laboratory work-ups, final diagnosis, treatment planning, the decision on discharge, etc.). 20% of physicians claimed that artificial intelligence changed their clinical decision making and one-third found that these algorithms affected their diagnostic work-ups and treatment planning. Overall, artificial intelligence was applicable to facilitate pattern recognition in medical imaging through detection, classification, image optimization, reducing exposure, and improving workflow.
4	Nida Aslam/Explainable artificial intelligence approach for the early Prediction of ventilator support and mortality in the COVID-19 patients[6].	To use explainable artificial intelligence (EAI) and deep learning models to predict mortality and identify of critically ill COVID-19 patients who need ventilation support.	5739 admitted the COVID-19 patients	Three the COVID-19 patients	Saudi Arabia	2022	Cross-sectional, retrospective	**Scales:** Not mentioned **Software:** the COVID-19 patients' dataset Python 3.9.7 TensorFlow Keras 2.5.2 Dalex 1.4.1 Matplotlib 3.4.3 Sklearn 0.24.2 Pandas 1.3.4 Numpy 1.19.5 **Hardware:** Not mentioned	The dataset contained demographic data on patients, laboratory work-up, radiologic findings, comorbidities, blood pressure, asthma, chronic obstructive pulmonary disease, diabetes, cirrhosis, hepatitis, and renal failure. The accuracy, sensitivity, specificity, Youden index, and area under the retriever operating curve were calculated to assess the effectiveness of the suggested model. The synthetic minority oversampling technique was used to balance the dataset.	Explainable artificial intelligence was used to predict the mortality and ventilation support in the COVID-19 cases using demographic and clinical data. The suggested model had high accuracy and an area under the curve (above 0.95). This model can be implemented to help physicians with decision-making for critically ill patients. In addition, it facilitates hospital resource allocation planning.

Therefore, it is recommended to further explore AI functionalities in pandemics and health care, including conducting clinical trial studies to investigate the effectiveness of this technology in the diagnosis and treatment of diseases, health policy-makers accepting and implementing these products, designing user-centered contents for AI applications, evaluating the readiness and acceptance of this technology in different countries, developing cost-effective AI products, providing sufficient infrastructure, improving computer literacy and educating the use of AI, and developing evidence-based educational contents for AI. Also, the introduction of AI will help the LMIC more using the smartphone technologies and better management strategies.

Conclusions

The COVID-19 pandemic has forced us to apply technology for self-sufficiency, self-care, and improved quality of life. It has highlighted the use of technologies in everyday life. AI is a highly promising technology used in various areas, including health care. In this study, a scoping review was carried out on the functionalities of AI in the COVID-19 pandemic. The functionalities included prediction, detection, and diagnosis. We also concluded that deep learning and machine learning approaches are the most common approaches in AI. Most studies have used deep learning (convolutional neural networks). The results can help researchers, health-care organizations, and policy-makers gain new insights on how this technology can potentially aid a proper response to the COVID-19 pandemic or other areas in health care, and how to put it into use.

Authors contributions. Milad Ahmadi Marzaleh and Naseh Shalyari were responsible for the study's conception and design. Milad Ahmadi Marzaleh and Naseh Shalyari searched the relevant databases and included the appropriate articles according to the study objective. At the same time, Milad Ahmadi Marzaleh supervised the whole study. All authors prepared the first draft of the manuscript. All authors did the data analysis, made critical revisions to the study for important intellectual content, and supervised the study. All authors have read and approved the final manuscript.

Financial disclosure. None declared.

Conflict of interest. The authors have no conflict of interests to declare.

Informed consent. Nil.

References

1. **Assaf D, Gutman Ya, Neuman Y, *et al.*** Utilization of machine-learning models to accurately predict the risk for critical COVID-19. *Intern Emerg Med.* 2020;15(8):1435-1443.
2. **Kolbe L, Jaywant A, Gupta A, *et al.*** Use of virtual reality in the inpatient rehabilitation of COVID-19 patients. *Gen Hospital Psychiatry.* 2021;71: 76-81.
3. **da Silva TD, de Oliveira PM, Dionizio JB, *et al.*** Comparison between conventional intervention and non-immersive virtual reality in the rehabilitation of individuals in an inpatient unit for the treatment of COVID-19: a study protocol for a randomized controlled crossover trial. *Front Psychol.* 2021;12:622618.
4. **Vlake JH, Van Bommel J, Hellemons ME, *et al.*** Intensive care unit-specific virtual reality for psychological recovery after ICU treatment for COVID-19; a brief case report. *Front Med (Lausanne).* 2021;7:1143.
5. **Gao Z, Lee JE, McDonough DJ, *et al.*** Virtual reality exercise as a coping strategy for health and wellness promotion in older adults during the COVID-19 pandemic. *J Clin Med.* 2020;9(6):2020:1986.
6. **Aslam N.** Explainable artificial intelligence approach for the early prediction of ventilator support and mortality in COVID-19 patients. *Computation.* 2022;10(3):36.
7. **Asadzadeh A, Samad-Soltani T, Rezaei-Hachesu P.** Applications of virtual and augmented reality in infectious disease epidemics with a focus on the COVID-19 outbreak. *Inform Med Unlocked.* 2021; 24:100579.
8. **Demers M, Martinie O, Winstein C, *et al.*** Active video games and low-cost virtual reality: an ideal therapeutic modality for children with physical disabilities during a global pandemic. *Front Neurol.* 2020; 11:601898.
9. **Mantovani E, Zucchella C, Bottiroli S, *et al.*** Telemedicine and virtual reality for cognitive rehabilitation: a roadmap for the COVID-19 pandemic. *Front Neurol.* 2020;11:926.
10. **Carlile M, Hurt B, Hsiao A, *et al.*** Deployment of artificial intelligence for radiographic diagnosis of COVID-19 pneumonia in the emergency department. *J Am Coll Emerg Physicians Open.* 2020;1(6):1459-1464.
11. **Tripathy S, Kabir R, Arafat S, *et al.*** Futuristic technologies for advanced detection, prevention, and control of COVID-19. In: *Diagnostic Strategies for COVID-19 and Other Coronaviruses*: Springer; 2020:161-173.
12. **Jalabneh R, Syed HZ, Pillai S, *et al.*** Use of mobile phone apps for contact tracing to control the COVID-19 pandemic: a literature review. 2021: 389-404. doi: 10.1016/j.arcmed.2020.05.015
13. **Zhou Y, Wang F, Tang J, *et al.*** Artificial intelligence in COVID-19 drug repurposing. *Lancet Digit Health.* 2020;2(12):e667-e676.
14. **Malik YS, Sircar S, Bhat S, *et al.*** How artificial intelligence may help the Covid-19 pandemic: pitfalls and lessons for the future. *Rev Med Virol.* 2021;31(5):1-11.
15. **Bai HX, Hsieh B, Xiong Z, *et al.*** Performance of radiologists in differentiating COVID-19 from viral pneumonia on chest CT. *Radiology.* 2020; 296(2):E46-E54.
16. **Hu Z, Ge Q, Li S, *et al.*** Artificial intelligence forecasting of Covid-19 in China. *arXiv.* 2002.07112. 2020 Feb 17.
17. **Shams AB, Hoque Apu E, Rahman A, *et al.*** Web search engine misinformation notifier extension (SEMiNExt): a machine learning based approach during COVID-19 Pandemic. *Healthcare.* 2021;9(2):156.
18. **Laguarta J, Hueto F, Subirana B.** COVID-19 artificial intelligence diagnosis using only cough recordings. *IEEE Open J Eng Med Biol.* 2020;1: 275-281.
19. **Vaishya R, Javaid M, Khan IH, *et al.*** Artificial Intelligence (AI) applications for COVID-19 pandemic. *Diabetes Metab Syndr.* 2020;14(4): 337-339.
20. **Hussain AA, Bouachir O, Al-Turjman F, *et al.*** AI techniques for COVID-19. *IEEE Access.* 2020;8:128776-128795.
21. **Khan M, Mehran MT, Haq ZU, *et al.*** Applications of artificial intelligence in COVID-19 pandemic: a comprehensive review. *Expert Syst Appl.* 2021; 185:115695.
22. **Hussain MW, Mirza T, Hassan MM.** Impact of COVID-19 pandemic on the human behavior. *Int J Educ Manag Eng.* 2020;10(8):35-61.
23. **Velayati F, Ayatollahi H, Hemmat M.** A systematic review of the effectiveness of telerehabilitation interventions for therapeutic purposes in the elderly. *Methods Inf Med.* 2020;59(2/03):104-109.
24. **Omboni S, McManus RJ, Bosworth HB, *et al.*** Evidence and recommendations on the use of telemedicine for the management of arterial hypertension: an international expert position paper. *Hypertension.* 2020;76(5):1368-1383.
25. **Doraiswamy S, Jithesh A, Mamtani R, *et al.*** Telehealth use in geriatrics care during the COVID-19 pandemic—a scoping review and evidence synthesis. *Int J Environ Res Public Health.* 2021;18(4):1755.
26. **Kalhori SRN, Bahaadinbeigy K, Deldar K, *et al.*** Digital health solutions to control the COVID-19 pandemic in countries with high disease prevalence: literature review. *J Med Internet Res.* 2021;23(3):e19473.
27. **Sun W, Bocchini P, Davison BD.** Applications of artificial intelligence for disaster management. *Nat Hazards.* 2020;103(3):2631-2689.
28. **Keshvardoost S, Bahaadinbeigy K, Fatehi F.** Role of telehealth in the management of COVID-19: lessons learned from previous SARS, MERS, and Ebola outbreaks. *Telemed J E Health.* 2020;26(7):850-852.

29. **Guo J, Li B.** The application of medical artificial intelligence technology in rural areas of developing countries. *Health Equity.* 2018;2(1):174-181.
30. **Mantena S, Celi LA, Keshavjee S, *et al.*** Improving community health-care screenings with smartphone-based AI technologies. *Lancet Digital Health.* 2021;3(5):e280-e282.
31. **Sheikh A, Bhatti A, Adeyemi O, *et al.*** The utility of smartphone-based artificial intelligence approaches for diabetic retinopathy: a literature review and meta-analysis. *J Curr Ophthalmol.* 2021;33(3):219-226.
32. **Wu L, He X, Liu M, *et al.*** Evaluation of the effects of an artificial intelligence system on endoscopy quality and preliminary testing of its performance in detecting early gastric cancer: a randomized controlled trial. *Endoscopy.* 2021;53(12):1199-1207.
33. **Kaelin VC, Valizadeh M, Salgado Z, *et al.*** Artificial intelligence in rehabilitation targeting the participation of children and youth with disabilities: scoping review. *J Med Internet Res.* 2021; 23(11):e25745.

https://doi.org/10.1017/dmp.2023.3 Published online by Cambridge University Press