



# Artificial intelligence as a fundamental tool in management of infectious diseases and its current implementation in COVID-19 pandemic

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## Abstract

The world has never been prepared for global pandemics like the COVID-19, currently posing an immense threat to the public and consistent pressure on the global healthcare systems to navigate optimized tools, equipments, medicines, and techno-driven approaches to retard the infection spread. The synergized outcome of artificial intelligence paradigms and human-driven control measures elicit a significant impact on screening, analysis, prediction, and tracking the currently infected individuals, and likely the future patients, with precision and accuracy, generating regular international and national data on confirmed, recovered, and death cases, as the current status of 3,820,869 infected patients worldwide. Artificial intelligence is a frontline concept, with time-saving, cost-effective, and productive access to disease management, rendering positive results in physician assistance in high workload conditions, radiology imaging, computational tomography, and database formulations, to facilitate availability of information accessible to researchers all over the globe. The review tends to elaborate the role of industry 4.0 technology, fast diagnostic procedures, and convolutional neural networks, as artificial intelligence aspects, in potentiating the COVID-19 management criteria and differentiating infection in SARS-CoV-2 positive and negative groups. Therefore, the review successfully supplements the processes of vaccine development, disease management, diagnosis, patient records, transmission inhibition, social distancing, and future pandemic predictions, with artificial intelligence revolution and smart techno processes to ensure that the human race wins this battle with COVID-19 and many more combats in the future.

**Keywords** COVID-19 · Techno-driven · Radiology imaging · Computational tomography · Industry 4.0 · Disease management

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## Introduction

Artificial intelligence is an essential tool in business, society, and healthcare today, where they maintain a critical balance between patient care aspects, administrative processes, and pharmaceutical organizations (Davenport and Kalakota 2019). The concept of artificial intelligence was initiated in 1956, and it involves “intelligent agents” or devices, which analyze the environment and perform to potentiate the processes (Crevier 1993). Therefore, it is the intelligence demonstrated by the machines mimicking and enhancing the human intelligence. Artificial intelligence is a process of acquiring data followed by its interpretation and learning to achieve the desired outcome (Elavarasan and Pugazhendhi 2020). In numerous healthcare paradigms, artificial intelligence is evidently considered to perform as well as or better than humans in disease diagnostics, such as artificial intelligence

components, outperforming radiologists in identifying malignant tumors as well as aiding researchers in formulation of cohorts in costly clinical trials (Davenport and Kalakota 2019). Artificial intelligence utilizes supervised and unsupervised learning processes, in which the former is the process of training and testing and is used to predict new data samples, whereas the latter is a learning process from data samples, without supervising it (Elavarasan and Pugazhendhi 2020). It is a collection of multiple learning (neural networks and deep learning), natural language processing, rule based expert systems, robotics, etc., which are the fundamental aspects of artificial intelligence (Davenport and Kalakota 2019). As one of the most common forms of artificial intelligence, machine learning is a statistical approach for fitting and training models with data to pursue learning (Davenport and Kalakota 2019; Mitchell 1997). About 63% of the companies were employing machine learning in their business, as per the 2018 Deloitte survey of 1100 US managers with artificial intelligence employing organizations (Deloitte 2018). Precision medicine is one of the common machine learning aspects in healthcare regimes, which deals with predicting whether a treatment protocol will succeed in a patient, on the basis of patient attributes and treatment considerations (Lee et al. 2018). Most of the machine learning and precision medicine parameter rely on a training dataset, which requires an outcome to be known, for example disease onset. This is referred to as supervised learning (Davenport and Kalakota 2019). Another complex parameter of machine learning is neural network technology, which has been prevalent in healthcare systems since decades, based upon neuronal signal processing, determining if the patient will acquire a specific disease (Davenport and Kalakota 2019). Deep learning and neural network models (Hinton 2018) are critical parameters of machine learning, which may possess a number of hidden variables, accessed by graphic processing units and cloud architectures (Davenport and Kalakota 2019; Hinton 2018). Deep learning has critical applications in cancer radiology, radiomics, and identification of significant clinical data, which is beyond what the human eye can perceive (Vial et al. 2018). The association of deep learning and radiomics has essential applications in diagnostics, overpowering the previous generation of image analysis tool, like computer aided detection (CAD) (Davenport and Kalakota 2019). Another significant role of deep learning involves speech recognition ability, as in natural language processing (NLP), which involves text translation and processing, creation, classification, and understanding of published research, clinical documentation, and other language related functions (Davenport and Kalakota 2019). NLP is a significant aspect of artificial intelligence that deals with human language analysis, which has been the goal of artificial intelligence researchers since 1950s (Davenport and Kalakota 2019). NLP comprises of two major components: statistical and semantic, where the former is based upon machine

learning, deep learning, and neural networks, requiring a large body of languages to learn (Davenport and Kalakota 2019). NLP is also capable of preparing clinical analysis and radiology reports of patients as well as interpreting patient interactions (Davenport and Kalakota 2019). Expert systems, in an organization, are a set of rules designed by human experts and professionals in a specific knowledge realm, to facilitate smooth conduct and clinical decision supporting parameters (Davenport and Kalakota 2019; Vial et al. 2018). However, problems arise when a large number of rules are formulated and tend to breakdown, due to alteration in the knowledge criteria, thereby posing difficulty and time consumption in changing the rules, which can be overcome by adopting reliable approaches, based upon machine learning and deep learning algorithms (Davenport and Kalakota 2019). Moreover, robotics has also emerged as an integral component of artificial intelligence in the previous years, with a number of roles to play in healthcare regimes, by significantly performing pre-defining tasks in industries and hospitals, as surgical robots, which were approved in 2000 in the USA, to incorporate capability of surgeons in machines to perform surgical procedures, currently been observed in gynecology, prostate, and head and neck surgery (Davenport and Kalakota 2019; Davenport and Glaser 2002). Diagnostics and treatment are fundamental approaches, targeted by components of artificial intelligence, as evident by MYCIN, developed by Stanford, which depicted appreciable results in diagnosis and treatment of blood borne bacterial infections (Bush 2018). IBM Watson attracted media attention recently for its potential in cancer diagnosis and treatment (Buchanan and Shortliffe 1984; Ross and Swetlitz 2017). Numerous tech firms and startups have begun to address artificial intelligence and handling the issues associated with it, like collaboration of Google with healthcare network to form predictions to warn to the clinicians of high-risk conditions (Rysavy, 2013). Similarly, a concept of “clinical services machine” is formulated by Jvion, identifying high-risk patients and the ones expensive to treatment options (Davenport and Kalakota 2019). Various artificial intelligence-based interpretation systems have been developed by Google, Enlitie, and other startups (Davenport and Kalakota 2019). Also, many healthcare firms have linked disease diagnostics with genetic interpretations, like Flatiron Health and Foundation Medicine, both now owned by Roche (Davenport and Kalakota 2019). Furthermore, many healthcare providers are also utilizing “population health machine learning models” to study the disease risk in specific populations (Rajkomar et al. 2018). Engaging patients to comply and adhere to the treatment plan is a common problem in the healthcare organizations and utilizing artificial intelligence and business approaches to drive and conceptualize the patients in this regard is a growing concern. Numerous healthcare regimes have also formulated chatbots to potentiate mental health services, telehealth, patient interaction, and

wellness (Davenport and Kalakota 2019; Utermohlen 2018). Furthermore, many studies have highlighted the impact and role of emerging healthcare technologies and digital mediums like mobile health, 5G, telemedicine, internet of things, artificial intelligence (AI), etc. on the pandemic, by acting as powerful weapons to combat the situation by preventing and controlling the infection spread (Ye 2020).

The review tends to localize the healthcare potential of artificial intelligence parameters to their employment in management of infectious diseases and the current issue of COVID-19 pandemic. The employment of artificial intelligence technologies in diagnosis, prediction, classification, analysis, treatment, and detection of corona virus infection is a matter of utmost importance, nowadays on account of its rapid transmission across the globe. The artificial intelligence programs utilize industry 4.0 technologies, information technology, internet of things, machine learning programs, mobile applications, deep and convolutional neural networks, and digital healthcare regimes in order to save time, overcome the problems of limited health workers, maintain a proper record of infected, recovered, and death cases, and public dissemination of information to target fast recovery and retardation of COVID-19 pandemic, simultaneously aiding the researchers in vaccine development, disease diagnosis, symptom abbreviation, and understanding the transmission cycle and genomic sequence of the virus. The review also enlists certain challenges associated with these techno-driven approaches and the future of artificial intelligence in healthcare management of infections during pandemics. The authors aim to scrutinize the significance of artificial intelligence and other emerging healthcare technologies in management of COVID-19 disease, where the manuscript details the positive impact of using such technologies, and how they minimize the time, cost, and human efforts, as well as provide efficient and reliable solutions in the pandemic. The authors have collaborated information and data collected from online datasets, like PubMed, Elsevier, etc. Artificial intelligence is a growing field that is constantly grabbing attention of the researchers from all areas. Its role in management of COVID-19 is well defined and is expected to significantly aid in promoting the regression of the pandemic.

### Artificial intelligence as a fundamental tool in the management of infectious diseases

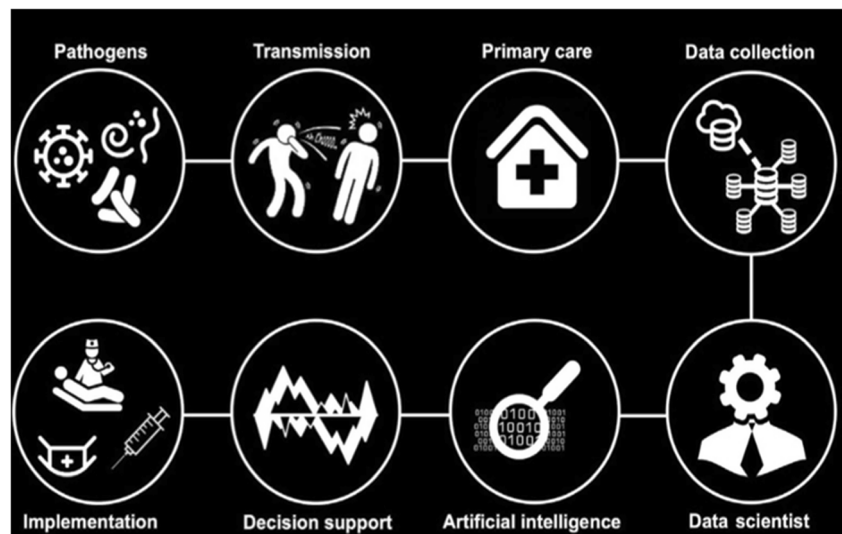
Infectious diseases are pathogen-derived diseases, caused by microorganisms like bacteria, viruses, fungi, or parasites and can be symptomatic or asymptomatic. The symptomatic and asymptomatic characteristics of infectious diseases do not account for detrimental effects of the diseases, as certain infections like HIV (human immunodeficiency syndrome) are symptomatic but produce uncontrollable adverse effects after

a few years (<https://www.who.int/topics/infectiousdiseases/en/>). The infection transmission either takes place through close contacts (sexual or blood contact) or via droplets (sneezing, coughing, and talking) (Agrebi and Larbi 2020). The infectious diseases have been responsible for the disabilities and deaths around the world, like the 1918-19 pandemic of Spanish flu, one of the deadliest influenza virus, infecting one-third of the global population (Taubenberger and Morens, 2006; <https://www.cdc.gov/features/1918-flu-pandemic/index.html>). Back then, the diagnosis, treatment, and prevention protocol of infectious diseases was limited, as there was minimum information about causative agents and viruses. Many countries failed to communicate the effects and death toll caused by the influenza virus and kept silence to maintain the public morale. As a result, the population all over the world suffered the disastrous consequences of the virus, depicting the harmful impact of poor communication of the pandemics. Following this problem, the World Health Organization's Global Influenza Surveillance and Response System (GISRS) has been tracking the evolutionary mechanisms of influenza viruses (Agrebi and Larbi 2020). Furthermore, the twenty-first century has witnessed various global pandemics, like SARS (2003), MERS (2014), Ebola (2014–16), and Zika virus (2015–16), that have significantly affected the global population (Agrebi and Larbi 2020). Artificial intelligence programs have been recognized as classical tools to identify early signs of infectious diseases and have become one of the essential principles of infectious diseases, as depicted in the Fig. 1.

### Improved diagnostic procedures and blocking transmission

Airport testing is one of the many steps to hinder the transmission of infection. Mathematical modeling associated processes are improving this type of surveillance (Agrebi and Larbi 2020). Similarly, a system of detection of infected individuals is developed using vital signs, like temperature, heart rate, and respiration rate (Sun et al. 2015). Various machine learning parameters have been employed in diagnosis, like Matlab, nested one versus one (OVO) support vector machine (SVM), leave one out cross-validation (LOOCV), and SVM learning algorithm, which are employed in a combined form by separation of genetic sequences from bacteria (Agrebi and Larbi 2020). The combined systems of high-resolution melt and SVM can identify 100% isolated bacteria (Fralely et al. 2016). A disease diagnosis system, similar to the immune system, which is concerned with identification and prevention of threats, is developed, known as artificial immune recognition system (AIRS), which utilized *k*-nearest neighbor (KNN) algorithm as the classifier (Agrebi and Larbi 2020). However, SVM utilizing artificial intelligence programs have shown better (Watkins and Boggess 2002; Cuevas et al. 2012)

**Fig. 1** Important principles in the management of infectious diseases



accuracy than those with KNN algorithms, due to less accuracy profile. SVM is a robust classifier, which is primarily used in tuberculosis cohort, on accounts for 100% specificity, 100% sensitivity, zero root mean squared error (RMSE), 100% accuracy, area under the curve (AUC) of one, and Youden's Index of one (Agrebi and Larbi 2020). Machine learning programs are used in diagnosis of infectious diseases like malaria, which possess time consuming diagnosis criteria and require multiple health services (Agrebi and Larbi 2020). Digital in-line holographic microscopy data analysis is an appropriate, cost-effective method of detection of infected RBCs in the blood of malaria infected patients (Go et al. 2018). Moreover, many machine learning algorithms are useful and accurate in separating healthy cells from infected ones for training and testing groups (Agrebi and Larbi 2020). These DIHM-based techniques of artificial intelligence do not require complex processing of blood samples (Agrebi and Larbi 2020). Epidemiology studies should be acquired in a specific timeline and can be performed at a population or individual level, where the data related to the infection is collected in a longitudinal manner (Agrebi and Larbi 2020). The intensity of the emerging disease can be predicted with mathematical models, such as prediction models and large datasets in case of non-communicable diseases (NCDs) (Agrebi and Larbi 2020). The infectious diseases are characterized with rapid transmission, detrimental effects, thus this severity and fatality of infectious diseases, which proceeds within a short duration of time, posing a dire need for the researchers to investigate and predict the location and future intensity of the epidemic, for which the mathematicians have been able to use machine learning algorithms, to not only estimate the size and location, but also to investigate the infection related variables, like mode of transmission, time of incubation, symptoms, treatment resistance, and so on, which are important factors in mitigating the spread of the infection (Agrebi

and Larbi 2020). The epidemiological studies promote significant predictions of epidemics, as evident by its contribution in Kyasanur forest disease, which is a viral infection brought in by ticks (Majumdar et al. 2018). The scientists have depicted improved prediction rates and location data to be achieved in future databases, via neural networks, to effectively control infection transmission (Agrebi and Larbi 2020). Deadly infectious epidemics like Ebola have created a need to potentiate the prediction methods, leading to utilization of techno-driven approaches, like logistic regression (LR), SVM classifiers (with good accuracy profile), single layer artificial neural network (ANN), and decision tree (DT), which have successfully developed a set of predictors to be utilized for different Ebola-related data combinations (Colubri et al. 2016). An autoregressive integrated moving average (ARIMA) model has been utilized by teams from different countries, like USA (Kane et al. 2014), New Zealand (Zhang et al. 2014), China, and South Africa (Adeboye et al. 2016), to predict future outbreaks, and has also been employed for epidemic time series forecasting (Agrebi and Larbi 2020). Seasonality and tuberculosis incidence analysis was carried out in South Africa, by using neural network auto-regression (SARIMA-NNAR) and seasonal ARIMA (SAR-IMA) (Mohammed et al. 2018). A Rift Valley fever disease (vector borne viral zoonosis in Africa and Arabic peninsula) was analyzed to identify infection associated determinants, using machine learning algorithms, which determined wild Bovidae richness, sheep density, and intermittent wetland as prime factors contributing to the landscape suitable for such outbreaks (Walsh et al. 2017). Furthermore, optimized ARIMA-generalized regression neural networks models were used for tuberculosis control and forecasting in Heng County in China, portraying superiority of ARIMA derivatives over ARIMA model in prediction of TB future incidence (Wei et al. 2017). In order to formulate optimized strategies for malaria intervention, various experts



have utilized disease simulation models to portray the effectiveness of artificial intelligence programs in such fields (Wilder et al. 2018). Such an approach was supplemented by the already existing dense information and data on malaria control paradigm (Wong et al. 2019; Okell et al. 2008). Mostly the accuracy profile of prediction models depends upon the specificity and quality of input data, rather than the quantity (Agrebi and Larbi 2020). Dengue hemorrhagic fever occurred as a result of inoculation of virus by mosquitoes, which is prevented by employing precautionary methods, like SVM with radial basis functions (RBF) to analyze and forecast the morbidity rate, in order to minimize the risks (Kesorn et al. 2015). In order to facilitate a standardized approach towards infection diagnosis and treatment, the technological strategies should also consider socioeconomic variables, to enable better response (Agrebi and Larbi 2020). Figure 2 elaborates the role of machine learning and expert systems in management of infectious diseases.

### Antimicrobial drug resistance and treatment

Drug resistance is a major problem associated with management of infectious diseases, like in malaria where resistance to

antiparasitic drugs is a primary issue (Blasco et al. 2017). The resistance of *P. falciparum* parasites towards artemisinin-based combination therapies has affected the therapeutic potential of these therapies, which were adopted 20 years ago (Agrebi and Larbi 2020). The artemisinin resistance occurred as a result of limited response of ring stages to drug action, as determined by mathematical models employing intra-host parasite stage specific pharmacokinetic–pharmacodynamic inter-relationships (Saralamba et al. 2011). The resistance to antibiotics is better analyzed due to availability of different databases (Jia et al. 2017), as the comprehensive antibiotic resistance database (CARD), which contains admirable data as a reference, elaborating molecular basis of antimicrobial resistance (<http://arpcard.mcmaster.ca>). CARD is a model designed to effectively analyze the intensity of antimicrobial resistance drug classes and their respective mechanisms (Agrebi and Larbi 2020). Machine learning has been observed to identify the antimicrobial potential of drug compounds as evident by certain studies (Wang et al. 2016). The results of employing machine learning approaches in prediction of responsiveness to mice tubercular infection have been reported by Ekins et al. (2016). Many studies utilize receiver operator characteristic (ROC) plots and curves as essential tools for

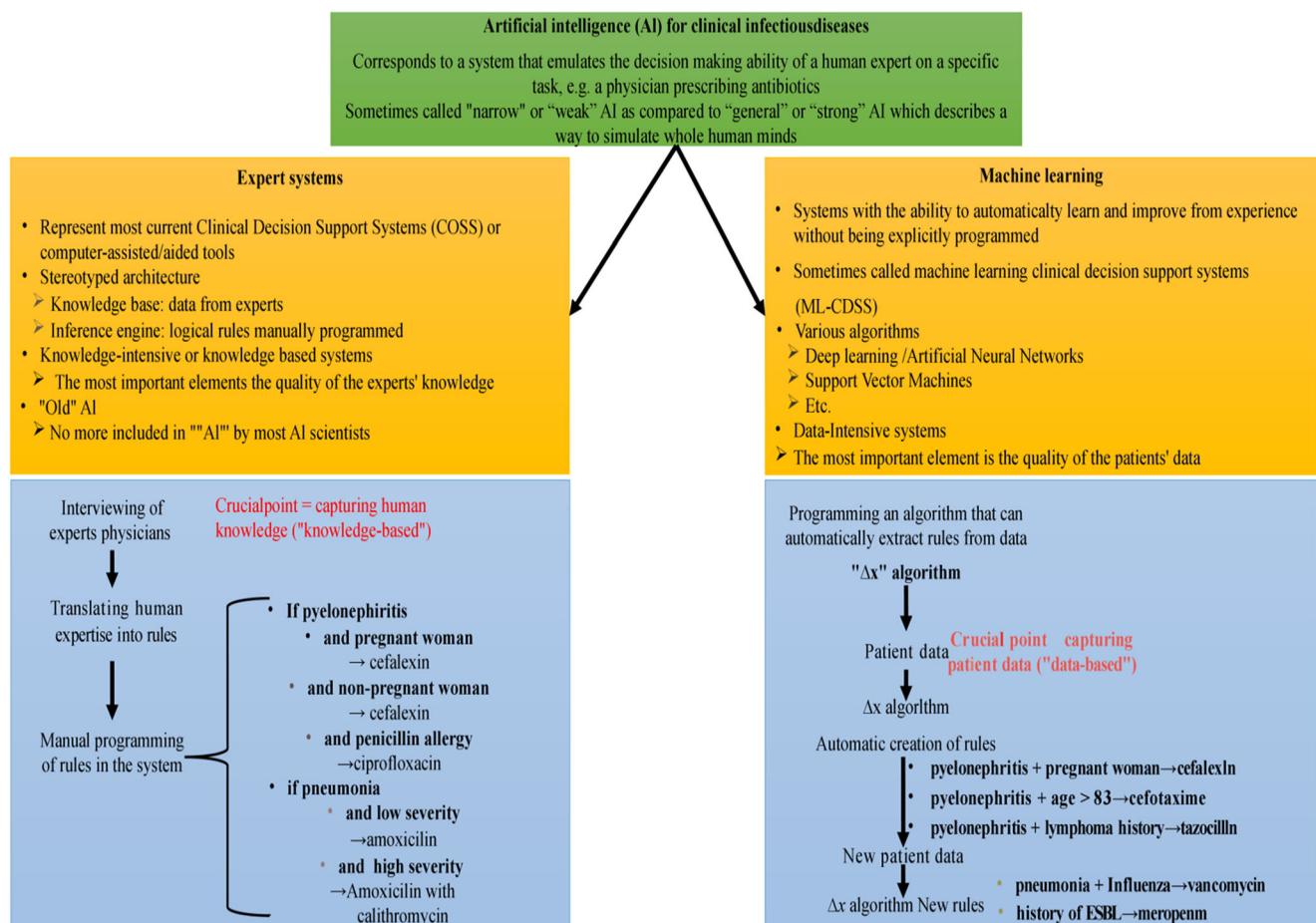


Fig. 2 Role of machine learning and expert system algorithms as essential artificial intelligence tools in management of infectious diseases

validation processes (Agrebi and Larbi 2020). Artificial intelligence algorithms like Naïve Bayes, C4.5 J48, and random forest are used to enhance the efficacy of models by developing economic and faster models, with good accuracy profile (Agrebi and Larbi 2020). Furthermore, treatment assistance with the help of mathematical models was depicted by Shen et al. who suggested the use of decision support system in planning the antibiotic treatment therapy to the patients based upon the patient report, contraindications, and drug-drug interactions (Shen et al. 2018). Numerous studies have illustrated that machine learning algorithms can be employed to identify best candidate vaccines (Choi et al. 2015). Another device was formulated to monitor accurate data related to the adherence of the patient to the treatment, which was more effective than self-reporting or pharmacy data, in which a cap device is fitted on the medicine bottle and recorded the time and date each time the bottle was opened and closed, generating a data, further analyzed by a super learner (Van der Laan et al. 2007). Various tools based upon artificial intelligence algorithms and their uses and outcomes in management of infectious diseases are depicted in Table 1.

## Artificial intelligence and emerging technologies in COVID-19 pandemic

The corona virus pandemic of 2019 (COVID-19) has taken over the entire world and is currently an issue of international importance (Elavarasan and Pugazhendhi 2020). The pandemic began with an outbreak in Wuhan (China), with first case identified in December 2019, soon spreading to all the corners of the world (Elavarasan and Pugazhendhi 2020). The WHO declared a COVID-19 outbreak as a Public Health Emergency of International Concern (PHEIC), on January 30, 2020 (WHO 2020). The current data reveals 3,820,869 infected patients all over the world and a death toll arising each day at alarming rates

with hundreds and thousands of death cases significantly reported (<https://www.worldometers.info/coronavirus/>). Countries like USA, Spain, Italy, etc. are the most affected nations with viral transmission taking place at a rapid rate, via human to human transmission by droplets or direct contact, and the incubation period of 14 days (Lai et al. 2020). This current crisis is exerting tremendous amount of pressure on healthcare authorities to develop effective diagnostic, treatment, and prevention approaches. The hospitals, healthcare facilities, and research centers are already putting in a lot of efforts to contain the infection and prevent the spread of the disease; however, every preventive measure taken by the government is associated with a number of challenges and problems on the way. The lockdown decision is collectively adopted by the world today but is exerting an economic imbalance in the whole world, and many developing nations are unable to carry it forward. Also, despite the effectiveness of diagnostic procedures adopted by the healthcare facilities, these methods are time-consuming and also less supply of medical equipment is creating difficulties in management of the pandemic. Moreover, the social balance is disrupted with people not being able to work and students experiencing great loss of academics, as a result of lockdown. All these problems point towards the development of effective alternative techno-driven approaches, which could significantly aid in carrying out all the necessary activities without virus transmission and also help the health professionals in diagnosis, treatment, and analysis of COVID-19 patients. Figure 3 layouts the general procedure of AI and non-AI based applications, aiding the healthcare professionals to identify COVID-19 symptoms in infected patients.

Increasing demand of emergency care facilities has broken down the best healthcare models worldwide (Xiaoxia 2020). Therefore, the global healthcare firms should focus on technological approaches and the world needs to promote development of healthy nations and not powerful nations. The healthcare today should significantly invest in preventive medicine, community health, and

**Table 1** Artificial intelligence algorithms and their uses and outcomes in management of infectious diseases

Artificial intelligence components	Outcomes	Infectious diseases
•Artificial neural network (ANN)	•Reducing diagnosis time and aiding in drug discovery	•Zoonosis
•Decision tree	•Health improvement	•Prediction of drug resistance
•Fuzzy clustering	•Identification of strategies for blocking viral transmission	•Outbreak
•ARIMA	•Cost effectiveness	•Host genetic
•Random forest	•Saving lives	•Drug discovery
•Unsupervised learning	•Personalized medicine	•Treatment therapy adherence
•Super learner	•Forensic approach	•Missing data
•KNN	•Aiding economically weak countries	•Pandemic and epidemic predictions
•Bayesian networks	•Decision support	•Pathogen mutation
•Support vector machine		•Source of infection

disaster management (Vaishya et al. 2020b). Most of the authorities were unable to judge the magnitude and intensity of this pandemic, as they failed to utilize the latest technologies in this regard. The need of artificial intelligence approaches is necessary to win this battle against the COVID-19 pandemic via effective roles in infection tracking, vaccine development, population screening, quarantine development, effective utilization of resources, and designing targeted responses (Vaishya et al. 2020a). Telecommunication departments are boosting their infrastructure and focusing on offering 5G functionality (Vaishya et al. 2020b). Mobile based apps are consistently providing information about regular infected, recovered, and death cases each day and connecting users to medical professionals through online portals (Vaishya et al. 2020b). Computational technologies are working synergistically with molecular biology techniques to accelerate the vaccine development processes (Vaishya et al. 2020b). New generation technologies have been exerting a significant impact on COVID-19 management with industry 4.0 technologies, newly developed smartphone apps and

tracking devices, internet of things, cloud computing, big data, 5G, blockchain, and many more, which are contributing to the global efforts in prevention, control, monitoring, tracking, vaccine development, treatment, and resource allocation of COVID-19 pandemic (Vaishya et al. 2020a). These technologies, similar to artificial intelligence, are a part of computer technology, however, function as physical devices based on the internet, while AI accounts for the concept of using such technologies to drive the output generated by human actions, therefore collectively constituting cyber-physical systems (CPSs) (Ghosh et al. 2018). Artificial intelligence, along with technology-driven approaches, like robotics, internet of things, telehealth, cloud computing, industry 4.0 technologies, convolutional neural networks, etc. are all modern era methods, which work hand in hand to reduce the workload, time consumption, and human efforts, as well as provide efficient and reliable results, not only in healthcare but all the other areas, influencing the life of human race. These approaches cannot work independently, but work conjointly, in order to achieve maximum

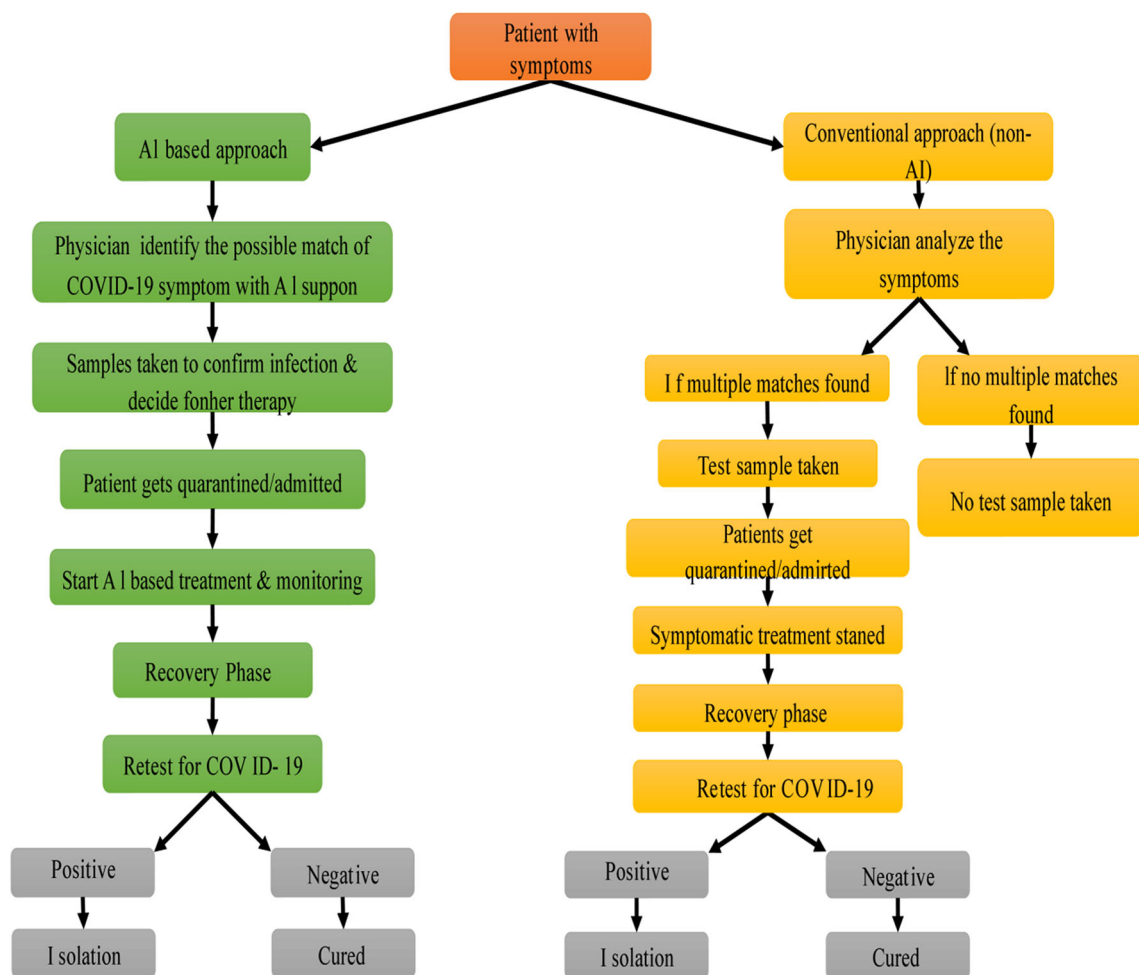


Fig. 3 General procedures of AI and non-AI based approaches to identify COVID-19 symptoms

outcome. Table 2 describes the technological approaches utilized in COVID-19 pandemic.

Artificial intelligence is associated with significant applications in the COVID-19 pandemic, comprising of early identification and screening of the infection by facilitating economical and rapid recognition of symptoms, using magnetic resonance imaging (MRI) and computed tomography (CT) (Vaishya et al. 2020a). Treatment monitoring is another application of AI in COVID-19 pandemic, which facilitates automatic prediction of virus spread, infected individuals, and keeping the people updated about the pandemic situation, along with contact tracing of the individuals, by identifying “hot spots” to trace the infection and predict the future course and chances of remission (Vaishya et al. 2020a). In addition, AI can identify the areas, individuals, and conditions most susceptible to the infection, as well as can keep a constant track of mortality rates and infection spread. Furthermore, most importantly, AI aids in development of vaccines and drugs by accelerating the drug development techniques, diagnosis processes, and clinical trial management in the pandemic (Vaishya et al. 2020a).

### Industry 4.0 technologies

Numerous advancements in technology and employment of technological measures, like artificial intelligence, synthetic biology, robotics, nanotechnology, etc. are all components of industrial 4.0 technology, which constitute the beginning of this revolution (Görmüş 2019). Artificial intelligence and industry 4.0 technology accelerate each other, resulting in propagation and empowerment of technological advancement in favor of mankind. Industry 4.0 technologies are technological approaches of 4th industrial revolution, which comprise of advanced technological processes to enhance atomization

and implement time saving processes, for the benefits of the human race (Javaid et al. 2020). The industry 4.0 technologies are connected to a monitoring system via sensors (Javaid et al. 2020). The industry 4.0 machines utilize smart techno processes for manufacturing, which are supported by wireless connectivity (Javaid et al. 2020). The industry 4.0 machines manufacture necessary disposable items to overcome their shortage during COVID-19 pandemic, by supplying disposal medical items and equipments to the health care institutions to facilitate smooth conduct of treatment to the patients (Zeng et al. 2020; Manogaran et al. 2017). This technology offers a flexible production line and comprises of numerous digital technologies, like AI and internet of things, to promote production and designing of medical instruments via designing software and manufacturing technologies, like 3D printing, etc. (Ruan et al. 2020; Haleem et al. 2019). This technology offers a number of digital solutions to accelerate the events during the pandemic (Cheng et al. 2016; Grasselli et al. 2020; Ahmed et al. 2020) and exhibits essential benefits like planning activities related to COVID-19, manufacturing of significant items required during the virtual reality employment for training, limited risks imposed to the health employees, maintains the medical part of the supply chain, robotics technology to fulfill limited number of doctors, promoting a flexible treatment environment, providing necessary aid to the researchers and helps in better assessment of possible risks as well as global public health emergency of this virus (Haleem and Javaid 2019; Ren et al. 2020).

The industry 4.0 technologies encompass a no. of technological approaches, to provide essential help and support during the pandemic (Javaid et al. 2020). It utilizes AI in population screening, risk assessment, and employing AI components (ML & natural language processing) to develop big-data based computational models for prediction and recognition of

**Table 2** Role of various techno-driven approaches in COVID-19 pandemic

Techno-driven approaches	Role in COVID-19 pandemic
Internet of things (IoT)	Connects the internet in the hospitals and the strategic locations, informing about errors and treatment alterations to the medical professionals
Robotics	Reliable approach undergoing jobs with precision and making intelligent decisions
Big data	Enables storage of extensive data in an efficient format
Telemedicine	Online portals enabling consultation from medical professionals through video conferencing, to limit social interaction and infection spread
Cloud computing	The important information is stored in a computational form, aiding in making real-time decisions in disease modeling
Drones	Automatic aerodynamic based vehicles for surveillance and transportation services
Smartphone apps	For receiving necessary information related to the COVID-19, and tracking and modeling disease outcomes
Additive manufacturing	Enables manufacturing of personalized devices for healthcare professionals, by employing 3D printing technology
Blockchain	Provides real-time information and traces the disease progression



the outbreak (Javaid et al. 2020). It also helps in reducing the viral transmission and eliminating the misleading and wrong viral related information on social platforms (Baldwin and Tomiura 2020; Haleem et al. 2020; Gupta and Misra 2020; Gupta et al. 2020). Moreover, AI-based video surveillance minimizes the workload of health care employees, especially during the pandemic, and helps in better understanding of the effect of virus on the population (Moeslund and Granum 2001; Wand et al. 2009; Sampol 2020; Kim et al. 2018; Pejic et al. 2006; Ren et al. 2020). Furthermore analytical approaches like big data track the spread pattern of the virus, storing large amount of related data, providing rapid re-evaluation of the decisions, which results in identification of effective therapies against the COVID-19 disease (Javaid et al. 2020). Therefore, this technique analyzes and forecasts the real time data from global sources to update the researchers, doctors, and epidemiologists with needful information and data. This set of technologies also employ virtual reality programs to enable video calling (to provide public connectivity and enable the people to continue their work) reducing travel costs, minimizing absenteeism as well as limits the environmental impact (Javaid et al. 2020). During the current global pandemic of COVID-19, virtual reality has been an outstanding tool enabling communication and comfort especially at this time. Cloud computing is another digital platform enabling people to maintain their professional and social lives via slack, loom, Netflix, Amazon, Google cloud, etc., even in the current times of social distancing (Javaid et al. 2020). One of the most unique AI programs, autonomous robots have offered a remarkable contribution at not only medical and healthcare platform but also in many other areas, as a revolutionary technology. In this COVID-19 pandemic, development of autonomic police robots to ensure social distancing can prove to be quite appreciable, with a greater degree of detection and accuracy by the machines, this technology can provide medical assistance to healthcare workers, overcoming the limited number of medical professional and saving a lot of time (Javaid et al. 2020). Furthermore, 3D scanning technologies can be used as a useful tool for analyzing the thoracic cavity of the patients infected with SARS-CoV-2 and detect the degree of severity in the individual (Javaid et al. 2020). Similarly, limited supply of face masks can be overcome by 3D printing technology (Javaid et al. 2020). It has been claimed that recently developed Nanohack; 3D-printed mask is reliable, reusable, and quite efficient against COVID-19 infection (Javaid et al. 2020). Biosensors are another significant components of industry 4.0 technology, which converts a bio signal into an electrical signal, that can be measured and provide devices which are cost effective, sensitive, and easy to operate, providing high accuracy in the present COVID-19 infection (Javaid et al. 2020). Furthermore, a single-use wireless biosensor patch is being developed, which is considered to facilitate early detection and monitoring of COVID-19

symptoms as well as real time recording of essential variables like ECG trace, temperature, respiration rate, etc. (Javaid et al. 2020). Moreover, these technologies provide telemedicine services, enabling detection and monitoring of physiological data and reporting the information to the health workers (Javaid et al. 2020). This digital platform enables remote and online learning as well as distance education during the COVID-19 pandemic.

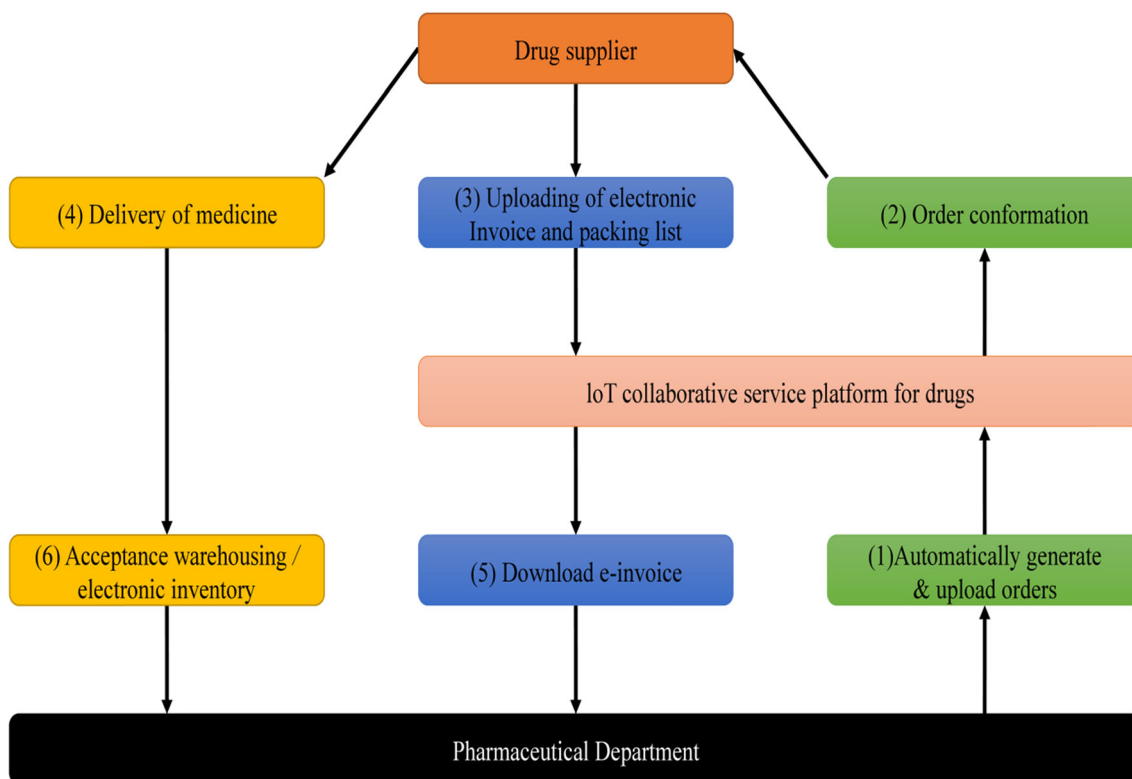
### Internet of things

Internet of things (IoT) is an automated approach that deals with collection, transfer, analysis, and storage of data, via biosensors and cell phone applications (Javaid et al. 2020). IoT is also useful in keeping a proper track of patient zero and infection chain as well as recognizing and tracking people who disobey the social distancing regulations (Javaid et al. 2020). This also supports the healthcare workers by in-home monitoring of the patients. IoT based service platform was observed to solve the issues related to drug delivery (Fig. 4), according to a Chinese study, which showed that the platform formulated hospital information system (HIS) based orders which are sent to suppliers to deliver medicines within a specific time (Ying et al. 2020). This approach of IoT curbed the infection spread via purchase of drugs and also preserved resources and labor costs (Elavarasan and Pugazhendhi 2020). The IoT comprises of drone technology, which is currently used for surveillance to ensure social distancing. The drones are automatic or remote controlled propelling vehicles based upon aerodynamic forces, which assist in transportation of goods, network of communication, and surveillance processes (Table 3) (Rosser et al. 2018).

In global pandemics like COVID-19, social disturbing is a significant aspect to prevent infection transmission and spread, thus, drones enable proper surveillance ensuring that the people follow the social distancing regulations, and also aid the police officials and ensure them to focus on more relevant services (Vacca and Onishi 2017; Mishra et al. 2020).

### Information communication, public dissemination of information, and social support in COVID-19 pandemic

During a pandemic, the public demands transparency related to the information, government initiatives, policies, quarantine periods, travel bans, and other updates. The information must be regularly updated and consistently verified by the authorities concerned along with risk assessment depending upon the dose of information. A simple model of government–expert–public–healthcare system has been presented for effective risk perception, which encompasses government–public, government–experts, experts–healthcare, and experts–public, as four critical mediums to control the decisive actions, that have



**Fig. 4** Workflow pattern of IoT based drug delivery paradigm

significant impact on the public (Elavarasan and Pugazhendhi 2020). The government–public communication is an external form of communication, comprising of delivery of accurate and complete data to the public, whereas, the government–expert communication is an internal form of interaction required for risk assessment and decision-making policies (Elavarasan and Pugazhendhi 2020). Expert–healthcare communication is also an internal form of communication, which is marked as a source for risk analysis and identifies the intensity of a problem, whereas, expert–public communication is

an external interaction to bridge the gap between the public and the experts, where the public fails to understand the complexity of the situation (Gesser-Edelsburg et al. 2015). Furthermore, one of the important lessons learnt from infected nations like Italy and China is that risk assessment is a very important parameter that should be considered and evaluated from the very beginning (Elavarasan and Pugazhendhi 2020). Dissemination of information to the general public is enabled by development of free interactive chat services, to promote regular release of updates related to the COVID-19 pandemic, also facilitating the users to ask questions related to the COVID-19 and stay connected with healthcare professionals (Kapoor et al.). AskNii, an online portal that was launched in India in the mid 2019, is an artificial intelligence based communication platform, that is currently being widened to incorporate necessary information related to the COVID-19 pandemic on its twitter handle (10.1016/j.ihj.2020.04.001 <https://twitter.com/asknivi?>). “Natural cycles,” a US based birth control app has also expanded to develop a symptom tracker with built-in functionality, to aid the COVID-19 crisis (Kapoor et al.). Numerous mobile based apps like Safiri Smart, CommCare, and Praekelt.org have been showcased in Global Digital Health Network convention, on 12th March 2020, in its first virtual COVID-19 session, to portray the role of such tech-based solutions in management of COVID-19 pandemic (<https://www.jsi.com/covid-19-digital-health-solutions-to-improve-theresponse/>). Many countries

**Table 3** Potential applications of drone technology

Application of drone technology	Description	Reference
Surveillance	<ul style="list-style-type: none"> <li>• As military weapons and mapping tools</li> <li>• Searching and rescuing</li> <li>• Ensuring that people stay indoors in current pandemic crisis</li> </ul>	Vacca and Onishi (2017); Mishra et al. (2020)
Goods delivery	<ul style="list-style-type: none"> <li>• Truck and drone delivery system</li> <li>• Parcel and passenger transportation</li> <li>• In infectious diseases</li> </ul>	• Crisan and Nechita (2019); Kellermann et al. (2020); Poljak and Sterbenc (2019)

have started sharing useful information related to the pandemic on specific apps and websites like “Corona Map” in South Korea (<https://coronamap.site/>). Moreover, the Indian government has formulated a mobile app, “Aarogya Setu,” to enable communication between healthcare organizations and public as well as releasing useful information regarding the pandemic (<https://play.google.com/store/apps/details?id%2Fnic.goi.aarogyasetu>). The COVID-19 pandemic exerts an undue burden on the society, as the people are panicking and are distant from their professional lives, thus desiring support and assistance during this difficult time. The viral transmission is a critical factor of this crisis and disease spreading would be maximum if the people would allow normal routines. Therefore, quarantine and social distancing parameters are significant approaches, which have been adopted by the whole world to manage the infection progression (Elavarasan and Pugazhendhi 2020). Work from home facilities enable the smooth conduct of isolation processes and are successfully carried out by video conferences and online portals like, zoom, webinar, etc. Various E-learning programs have been introduced in numerous countries like India, USA, South Korea, UK, etc., where the educational institutions have been closed to cease the infection spread (EdTechReview 2020). E-learning is a web-based technology that is created for distance learning such as Coursera, Google Classroom, and Udacity (Zoroja et al. 2014; Babu and Reddy 2015). Online competitions are also conducted in countries like India, to encourage young minds to develop innovative ideas and better solutions (Elavarasan and Pugazhendhi 2020). Surveillance programs have also been introduced to track the infected individuals to hinder the spread of the infection. A mobile application called Trace Together was launched in Singapore, which employed phone Bluetooth facility to detect COVID-19 infected individuals (Elavarasan and Pugazhendhi 2020). In Hong Kong, a wristband synced with mobile app alerted the authorities if the individuals leave the paces of quarantine (CNBC 2020).

### Supply chain and tele-health facility

Consistency in the availability of essential medical equipment is a challenging parameter in current global crisis. Dyson Ltd. (Tech company in UK), in collaboration with the Technology Partnership (TTP), has developed a brand new ventilator called Covent, as per the clinical standard (Techcrunch 2020). Moreover, medical tools are being developed using 3D printing technology, like Isinnova (3D printing company in Italy) which developed a valve, using a 3D printer which connected the hospital respirator to the mask (World Economic Forum 2021). AI technology has been employed in the hospital for collecting the patient data, as the number of patients is increasing day by day, during the current global crisis (Jordona et al. 2019). The American College of Physicians and American College of Cardiology issued a

collaboration statement, on 2nd March 2020, stimulating the authorities to understand the importance of telehealth services and digital health care in management of COVID-19 pandemic (Kapoor et al.). Many virtual chatbots and webbots have been created to enable healthcare workers (HCWs) to communicate with the patients virtually instead of risking exposure to infection (Kapoor et al.). Robotic telemedicine approaches like Vici (by Intouch Health) are incorporated with medical tools, cameras, and communication screens and can be sent into isolation wards of the patients to limit infection spread (Kapoor et al.). Various countries like China have employed robots for delivery of necessary items and sanitizing the hospitals (The Economic Times 2020). Electronic intensive care units (e-ICUs) are a unique approach enabling monitoring of 60–100 patients simultaneously by HCWs across different hospitals, as in USA where 300 hospitals in 34 states are taking advantage of this technology (Kapoor et al.).

### Convolutional neural networks

The medical imaging, reverse transcription polymerase chain reaction (RT-PCR), and computational tomography are significant parameters of diagnosis of COVID-19 disease in patients (Ardakani et al. 2020). The chest CT scan findings reveal presence of ground glass opacities and multifocal patches in patients with COVID-19 infection. Lodwick, in 1966, introduced the concept of computer aided diagnosis (CAD) (Lodwick 1965), which are currently employed in clinical practices. The reproducibility and sensitivity of CAD programs grant it superiority over radiologists (Castellano et al. 2004), who utilize CAD assistance in detection of lung problems in the present times. CAD is utilized in various technical frameworks designed for COVID-19 diagnosis as the role of convolutional neural networks (CNN), in detecting lung nodules as depicted by Gu et al. (2018). This concept was elaborated in a study, utilizing CAD based deep learning system to differentiate between COVID-19 infection and other viral diseases, via 10 well known CNNs, Alex-Net, VGG-16, GoogleNet, MobileNet-V2, SqueezeNet, ResNet-101, ResNet-18, Xception, ResNet-50, and VGG-19 (Fig. 5). All these CNNs were employed to distinguish the infection in COVID-19 group from non-COVID-19 group (Ardakani et al. 2020) (Table 4).

A study was conducted on COVID-19 positive 108 patients comprising 48 females and 60 males with an average age of  $50.22 \pm 10.8$  (Ardakani et al. 2020). The control group comprised of 86 patients with atypical pneumonia including 35 females and 51 males, with an average age of  $61.45 \pm 15.04$  (Ardakani et al. 2020). No marked variation was observed in COVID-19 and non-COVID-19 groups on the basis of sex distribution, but the average age in case of non-COVID-19 group was higher than COVID-19 group (Ardakani et al. 2020). Five hundred ten image patches, each

**Fig. 5** Representation of 10 convolutional neural networks, used to distinguish infection in COVID-19 and non-COVID-19 groups



from COVID-19 and non-COVID-19 groups, were extracted (total of 1020 image patches), and the data was divided into 102 (with 50%-50% distribution) and 816 (with 50%-50% distribution) for validation processes (Ardakani et al. 2020). The CNNs were able to differentiate between COVID-19 and non-COVID-19 groups with best results achieved by Xception and ResNet-101 networks (Ardakani et al. 2020). The ResNet network-101 exhibited greater sensitivity in

COVID-19 diagnosis, but lower specificity than Xception network. Therefore, ResNet-101 has a superiority over other CNN networks on account of its high sensitivity and AUC, elaborating residual learning, which are easily optimized and accuracy is improved with increasing depths (He et al. 2016). This model does not impose hefty costs and therefore, can be employed as an additional method during CT imaging in radiology departments (Ardakani et al. 2020).

**Table 4** Brief overview of convolutional neural networks used in distinguishing COVID-19 and non-COVID-19 groups

Convolutional neural networks	Description	References
(a) VGG-16	16 layers combination (3 fully connected and 13 convolutional layers)	Simonyan and Zisserman (2014)
(b) AlexNet	8 layers deep CNN (3 fully connected and 5 convolutional layers)	Krizhevsky et al. (2012)
(c) VGG-19	19 layers combination (3 fully connected and 16 convolutional layers)	Simonyan and Zisserman (2014)
(d) SqueezeNet	Compact CNN with up to 18 layers	Iandola et al. (2016)
(e) GoogleNet	Deep model trained on either ImageNet or Places 365 datasets	Szegedy et al. (2015)
(f) MobileNet-V2	Light weight CNN with 53 layers (1 fully connected and 52 convolutional layers)	Sandler et al. (2018)
ResNet	Deep network based on residual learning	He et al. (2016)
(g) -18	(a) 18 layers deep	
(h) -50	(b) 50 layers deep	
(i) -101	(c) 101 layers deep	
(j) Xception	Depthwise separable convolutional layers	Chollet (2017)



## AI in prediction, prevention, classification, diagnosis, tracking, and treatment of COVID-19 patients

AI and ML algorithms are intensively employed in classification and forecasting of data such as Blue dot start up based on AI, which analyzes vast no. of articles (>100,000) online worldwide in 65 different languages for every 15 min (Elavarasan and Pugazhendhi 2020). The algorithm identified accelerated increase in pneumonia cases in Wuhan, releasing warning, long before it was officially identified as the COVID-19 (Diginomica 2020). Analyses of health reports and tracing of infection hubs are carried out by AI based companies like Metabiota and Blue dot, which utilize NLP programs (Elavarasan and Pugazhendhi 2020). In order to facilitate clear understanding of an infection and analyze its severity from mild to critical condition, data prediction and classification is an important parameter to follow (Elavarasan and Pugazhendhi 2020). Jiang et al. utilized AI algorithms to investigate COVID-19 outbreak and patients critically infected, based upon the data collected from two hospitals in Wenzhou, Zhejiang (China) (Jiang et al. 2017). The results obtained from its predictive model were accurate up to 70–80% (Elavarasan and Pugazhendhi 2020). Furthermore, an AI algorithm based upon patient information was developed to predict the mortality rate of COVID-19 pandemic (Wang et al. 2020a). Supervised learning techniques and ML algorithms are employed in designing of prognostic markers (Zlobec 2005), alongside artificial neural networks (Zafeiris et al. 2018; Bertolaccini et al. 2017). AI has number of applications not only in prediction and classification but also in diagnosis of infectious diseases like COVID-19 (Elavarasan and Pugazhendhi 2020). Machine learning models, digital datasets, and deep learning algorithms are used to detect the infection in patients (Elavarasan and Pugazhendhi 2020). The AI parameter is employed in ophthalmology, dermatology, radiology, and pathology (Kulkarni et al. 2020). The routine diagnostic procedures for COVID-19 detection are time-consuming and require accuracy thus a time saving and accuracy centered approach is required (Elavarasan and Pugazhendhi 2020). Deep learning method was employed radiological diagnostic procedure of COVID-19 and 85.5% accuracy in internal evaluation and 95.2% accuracy in external validation was observed (Wang et al. 2020b). A CAD4TB software based CAD4 COVID screening program is developed by Thirona and Delft Imaging which is currently being employed in COVID-19 screening (ITN 2020). Stand-alone diagnostic booths have been developed as an innovative approach to facilitate off site COVID-19 testing, countries like South Korea, where it is conceptualized as “drive-three” testing station to limit the exposure to health care service

providers and conserve use of PPEs (Kapoor et al.). Integrated health information systems (IHIS) of Singapore, in collaboration with Kronika, has developed a temperature screening solution using iThermo, which precludes the requirement manual temperature checks (Kapoor et al.). Use of wearable devices to track heart rate, temperature, sleep duration, and other variables can prove to be efficient in management of COVID-19 infection. Apple in collaboration with CDC, FEMA, and the White House coronavirus task force has developed as Apple Health Check app to serve as infection screening portal and enables the users to answer questions related to infection further directed about steps to follow (Kapoor et al.). “Siri give me guidance” is a voice-based Siri update guiding about symptoms of COVID-19 and telehealth app links to follow. On account of greater susceptibility of geriatrics to COVID-19 infection, Alexa has launched “My Day for Seniors” to enable virtual screening of elderly population (Kapoor et al.).

To overcome the problem of ventilator setting in treatment of diseases, Ganzert et al. utilized a ML based approach to determine pressure volume curve in artificially ventilated patients with respiratory problems (Ganzert et al. 2002). This approach can prove to be useful in potentiating COVID-19 treatment regimes. Furthermore, intelligent fault diagnosis is another aspect of ML algorithm in which models are developed to detect the machine faults (Lei et al. 2020). Stratifyd, a data analyst company, utilizes AI algorithms to scan the social platforms post and cross referencing them with disease description from official sources like WHO for animal health, etc. (MIT Technology Review 2020a). Ramesh Raskar and MIT Media lab team designed an app, Private kit: safe paths to track the traveling path of an individual and detecting whether that individual has come in contact with another infected individuals (MIT Technology Review 2020b). Furthermore, reports have revealed the availability of open research data set related to COVID-19 containing research and review papers from reputed journal and sources like bioRxiv and medRxiv, aiding the researchers to a great extent (Elavarasan and Pugazhendhi 2020). AI algorithms are also useful in maintaining medical records, especially when the no. of patients is increasing day by day in COVID-19 pandemic (Crevier 1993). AI can also be used for identification of useful drugs and accelerated vaccine development process in COVID-19 pandemic (Gupta et al. 2020). It is also helpful in conduct of clinical trials related to COVID-19. AI algorithms can evaluate the intensity of viral infection by contact tracing of the individuals and identification of hotspots (Vaishya et al. 2020a). Various other companies have contributed in management of COVID-19 pandemic by aiding in manufacturing of medical equipment and products, as depicted in Table 5 (Elavarasan and Pugazhendhi 2020).

**Table 5** Numerous companies manufacturing medical tools and products during COVID-19 pandemic (Autodesk-Redshift 2020; NS Medical devices 2020; World Economic Forum 2021)

Companies	Field	Manufacturing products	
		Before pandemic	After pandemic
Gucci and Zara	Fashion	Luxury clothing and apparels	Surgical masks
Ford	Automotive	Vehicles	Respirators and ventilators
Bacardi	Alcohol based company	Rum	Hand sanitizers
Dyson	Tech company	Hand dryers and vacuum cleaners	Ventilators
Airbus	Aerospace industry	Aircraft equipments	Ventilators
Mercedes	Automotive	Vehicles, formula 1 engines	Continuous positive airway pressure (CPAP) machines
Ineos	Chemical based	Chemicals, gas, plastics, oils	Hand sanitizers
L'Oreal	Fashion	Creams and perfumes	Disinfectants and sanitizer gels

## Challenges and future perspectives

Besides the practical applications of artificial intelligence technologies, these approaches require stringent examination for processes related to security, confidentiality, and privacy. It is considered to replace humans in numerous fields, therefore, emerging as a constant threat to human race. Employing AI programs in maintaining patient records, keeping track of infected patients, transportations, surveillance, social interactions, diagnostic and treatment approaches and many other applications occupy a major part of healthcare services, thus replacing man power in every aspect, resulting in unemployment problems and false utilization of technology. This can be prevented by introducing an innovative approach of “human in the loop” in the near future (Patel et al. 2019). Patel et al. carried out a recent study on artificial intelligence based deep learning models for carrying out infection diagnosis in patients, which are controlled by radiologists appointed at key checkpoints, where the program faced difficulties (Patel et al. 2019). The COVID-19 outbreak not only affects the healthcare authorities but also influences innovation, businesses, livelihoods, and infrastructure, thus, the future researchers should target on all aspects that a pandemic affects and focus should be put on preventing viral transmission in rural areas as well. Various community-based apps, like Nextdoor app, offer support to the public by delivering essential items at the doorstep during lockdown conditions (Kapoor et al.). Numerous mobile phone apps have been designed to enable the facilities of work from home and conduction of examinations and classes by educational institutions. Harmonizing artificial intelligence integration with healthcare institutions to promote analysis, prediction, diagnosis, and treatment of COVID-19 disorder is an important concern, which requires

establishment of guidelines and regulations by the government on its behalf, as the Indian government which has issued certain guidelines, depicting that RMP is allowed to provide telemedicine consultation in to patients in India, keeping in consideration the ethical and professional standards (Kapoor et al.). Also, in the USA, under the Health Insurance Portability and Accountability Act (HIPAA), it has been declared that an individual would not be charged with a penalty for not complying with HIPAA rules, for the “good faith provision of telehealth during COVID-19 nationwide public health emergency” permitting the use of online portals, like zoon, Facetime, Google, Skype, etc., to maintain social connections (Kapoor et al.). Moreover, US legislations have declared that telehealth facilities should be deployed for both COVID-19 and non-COVID-19 groups (Kapoor et al.). USFDA has also approved medical devices, ECGs and its OTC software, blood pressure monitors, thermometers, pulse oximetry, respiration monitors, electronic stethoscopes, and cardiac monitors, which utilize wireless connectivity programs and have the ability to deliver patient related data to the HCWs directly, minimizing social contacts (Kapoor et al.). A very common problem associated with tech-based online portals and social websites is release of false updates related to the pandemic, misleading the general public. To prevent transmission of unnecessary and irrelevant information regarding the current COVID-19 crisis, many websites and online platforms have taken stringent measures. Facebook has blocked all COVID-19 related information platforms except official sites (Elavarasan and Pugazhendhi 2020). Pinterest made all its COVID-19 related search and posts to be approved by WHO (Elavarasan and Pugazhendhi 2020), therefore, minimizing the spread of misinformation related to COVID-19 pandemic.

## Conclusion

The corona virus outbreak has affected thousands of individuals across the globe posing immense threat in the current times. Techno-driven approaches in governance, coordinating public behavior, and optimizing healthcare services can help in mitigating the risks of COVID-19 infection. The review highlighted the importance and significance of artificial intelligence and its components, including ML, ANN, DL, NLP, and expert systems, in diagnosis, prevention, and curbing the COVID-19 transmission worldwide, in the first section. Potential involvement of AI platform in management of infectious diseases offered a generalized approach to understand and analyze the extent of utilization of tech-based programs to alleviate infectious diseases. This formed a crucial part of the second section of the review, emphasizing on improving the diagnostic procedures, blocking viral transmission, and aiding in epidemiological studies in management of infectious diseases. The third section of the review elaborated the currently employed AI algorithms in abbreviating the risks of COVID-19 infection and supplementing the processes of diagnosis, prediction, prevention, analysis, treatment, vaccine development, and transmission inhibition of COVID-19 infection. This section represented a detailed analysis of industry 4.0 technologies, information communication portals and maintaining social networks via mobile phones, enabling telehealth facilities (telemedicine and teleconsultation), role of DL based convolutional neural networks in differentiating COVID-19 from non-COVID-19 groups and a comprehensive description of role AI paradigms in diagnosis and treatment of COVID-19 patients, and how these tech-based programs accelerate the processes vaccine and drug development in a global crisis like this, saving time, labor, and costs and overcoming the limited supply of medical equipment and health professionals.

It is quite certain that the human race would eventually heal from this COVID-19 pandemic, but the question is how fast can we exterminate this threat, and how many lives can we save on the way. The healthcare professionals, researchers, police authorities, and other service providers are doing an appreciable job in abolishing the risks of the infection and keeping the people safe. Employment of artificial intelligence accelerated this approach and strengthens the efforts made by the people all over the globe, serving as a pioneering weapon, to enable the human race win this battle against the COVID-19 pandemic.

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