# AI&ML for Medical Sector

Subjects: Computer Science, Artificial Intelligence | Engineering, Biomedical | Others

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This work represents a comprehensive analysis of the potential AI, ML, and IoT technologies for defending against the COVID-19 pandemic. The existing and potential applications of AI, ML, and IoT, along with a detailed analysis of the enabling tools and techniques are outlined. A critical discussion on the risks and limitations of the aforementioned technologies are also included.

Keywords: COVID-19 ; IoT ; ML ; AI ; coronavirus ; machine learning ; artificial intelligence

## 1. Introduction

Humanity is now encountering a global crisis, perhaps the greatest crisis of this generation: the COVID-19 pandemic. People all over the world came to know this disease first on 31st December 2019, when the Wuhan Municipal Health Commission, China, reported a cluster of cases of pneumonia in Wuhan, Hubei Province which was ultimately identified as a novel virus named SARS-COV-2 resulting in the disease named “coronavirus disease 2019”, also known as COVID-19. On 13th January 2020, officials confirmed the first recorded COVID-19 case outside of China. After the disease started spreading all over the world, the World Health Organization (WHO) categorized this epidemic as a pandemic on 11th March 2020 [1]. As of 24th August 2020, COVID-19 has spread over 213 countries and territories around the world, resulting in over 23,586,023 reported cases of confirmed contamination and 812,527 deaths [2][3]. Figure 1 illustrates COVID-19 spreading over time, which is very alarming as the rate of the new victims is rising at a significantly higher rate. Some of the countries, such as Australia, that experienced a decreasing number due to social distancing, are also facing a second wave of the COVID-19 pandemic.

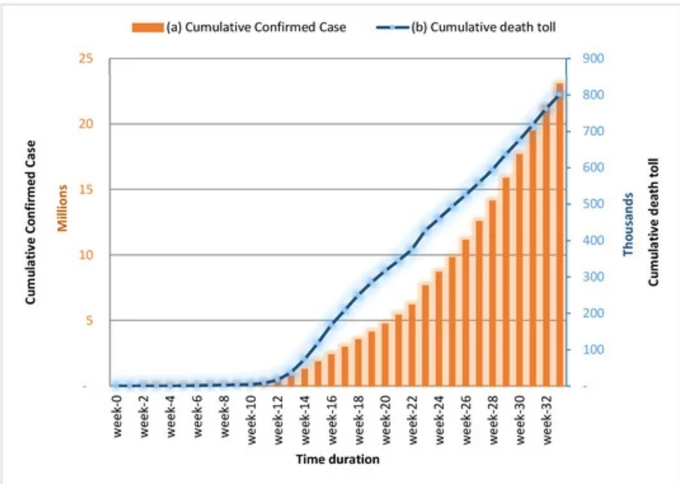


**Figure 1.** The statistics of the coronavirus disease 2019 (COVID-19) disease outbreak over the world, the figure shows (a) the accumulative figure of confirmed infected cases and (**b**) the accumulative figure of deaths.

The healthcare sector has put a great effort into COVID-19 diagnosis, screening and treating the infected individuals to address this pandemic. Governments and international organizations are aiming to organize an appropriate level of healthcare to mitigate the disease. To date, no medicine or vaccine has been invented to encounter this disease with complete assurance. So, different treatment methods and different medicines are applied as appropriate to remedy against this disease. On the other hand, authorities are imposing measures such as social distancing, area lockdown, the use of proper sanitization, etc. to prevent the further spreading of this pandemic. Therefore, to prevent the spreading of this disease, a collective effort is needed from all social entities such as the international organizations, governments, healthcare systems, and more essentially from the community. Moreover, the widespread integration of prospective technologies with effective healthcare management and resilient governance will reinforce the capacity to protect the society from COVID-19 disease [4].

With the emergence of intelligent technologies in this age of information from the global context, advanced artificial intelligence (AI) techniques promise massive applications in a variety of sectors. Figure 2 exhibits artificial intelligence and its subsections, especially from a machine learning (ML) point of view [4]. Although social distancing and the use of masks/gloves have been proven effective to slow down the spread, effective countermeasures and defense strategies need to be developed to build resilience against the pandemic through better monitoring and control. AI and ML, which have been successfully applied in a wide range of research areas, may have numerous prospective applications for achieving protection from COVID-19 disease. AI and ML can play a significant role in addressing the healthcare and social sector challenges caused by the COVID-19 pandemic. On a molecular level, AI can be utilized to approximate the construction of SARS-COV-2 associated proteins, classify present medications that can possibly be used as a remedy for the disease, suggest novel composites that can possibly contribute to the medicine development, design the potential objectives of the vaccine, and develop identification procedures as well as better realization of the virus contamination and severity level. From a medical viewpoint, AI can help improve the COVID-19 identification by analyzing medical imaging, offer different methods to study disease progression utilizing appropriate tools, and produce forecasts on infection spread based on compound statistical feedback, including digital medical history. From a societal standpoint, AI can be utilized for epidemiological exploration modeling, experiential statistics, including predicting the number of cases given different public policy choices. Sharing and presenting research ideas, along with extracting insights from statistics and simulations, are vital to speed up the response against the pandemic [5]. In such cases, the Internet of Things (IoT) can play a major role. AI coupled with IoT is more powerful in terms of the intelligent decision making and can help fight against this pandemic.

The Allen Institute for Artificial Intelligence is now sharing a digital library of articles that provides free access to COVID-19 data [6]. This database presently comprises over 44,000 articles; among them, 29,000 are full-text journals. Conjoining this database with other raw statistics from web links or social media can reveal further information and insights about the early detection and control of future outbreaks of SARS-COV-2 virus. Outbreak Response Management and Analysis System (SORMAS) and HealthMap are examples of surveillance-mapping tools that work online and allow early detection of contagious diseases in contrast to commonly used epidemiological methods. At this time, SORMAS and HealthMap are utilized for the observation of the COVID-19 situation [7]. On the other hand, The British Society of Thoracic Imaging (BSTI) and Cimar UK's Imaging Cloud Technology [8] have deployed an easy to access, open for all encrypted web platform to share imaging of patients identified or suspected to have COVID-19 [9]. The BSTI is creating a database containing imaging of confirmed patients with COVID-19 from these uploaded cases for further research. The goal is to broadcast new medical and investigative guidance quickly to medical service providers all over the country, utilizing these actual imaging samples [9].

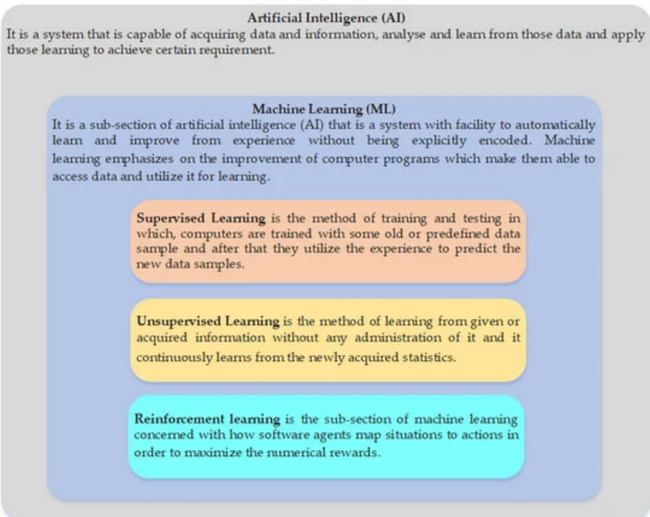


**Figure 2.** The relation between artificial intelligence and its components [10].

## 2. Application of AI and ML for the Medical Sector

AI and ML in the medical sector have a broad range of applications, including the prediction and classification of statistical information. In particular, BlueDot Toronto, which was developed by infectious disease scientists to research innovative solutions for mitigating the initial SARS outbreak, designed the first risk-based solution for detecting the outbreak of SARS-COV-2 virus [11]. This successful demonstration of AI and ML in predicting disease outbreaks applied BlueDot's prior research on the SARS outbreak to implement advanced technologies. A report stated that BlueDot employed a disease-monitoring framework that scrutinized over 100,000 online documents globally in 65 languages every 15 minutes

[4]. This system identified unusual statistics of pneumonia cases with unidentified cause in Wuhan, the ninth most populated city in China, and it warned about the occurrence of the disease considerably earlier than when it was formally recognized as COVID-19 [4]. Therefore, these advanced technologies can forecast such epidemics and create awareness among people to take the required pre-cautions for encountering the outbreaks.

Artificial intelligence application in detecting infectious diseases is extremely valuable in the medical sector and can bring revolutions to the healthcare practices. Integrating AI in the imaging processes has received significant attention within the healthcare sector. Machine-learning prototypes can scrutinize the medical images to identify the sickness at an initial phase. Such prototypes are driven by big data and deep learning algorithms to achieve the particular task. The prospective sectors where this image-oriented learning is possibly applied are pathology, ophthalmology, radiology, and dermatology [4]. The mitigation of diseases such as COVID-19 massively depends on the screening of people through pathogenic testing, which is a time-consuming process, and hence, precision is a must. In a study, the author introduced a medical identification process for COVID-19 based on radiographic variations in computerized tomography (CT) scans by implementing the deep learning process, which achieve 85.2% accuracy in the testing and validation stage. [4].

Machine learning can assist the work of medical professionals by analyzing and organizing an enormous amount of patient information stored in digital medical records. Moreover, Machine Learning is applied in different medical applications that include detecting patients with severe conditions who urgently require intensive care unit (ICU) facilities, identifying early symptoms of diseases, understanding the breathing condition of the patient by analyzing chest X-rays, etc. Therefore, AI and ML improves the performance of identification and prediction process and how administrative decisions are made in the medical sector [4]. In these circumstances of the COVID-19 pandemic, the aforementioned technologies have already aided medical professionals encountering the situations in a significantly effective manner.

## 2.1. Medical Imaging for COVID-19 Patients

Medical imaging such as CT scan and X-rays are widely used for diagnostic and treatment purposes. During the COVID-19 pandemic, the role of CT scan and X-ray imaging are very important for SARS-COV-2 virus detection. For this purpose, the emerging technologies such as AI and ML reinforce the imaging analysis by intelligent detection and classification of the abnormalities. For instance, AI-enabled disease type classification will help toward automation of the screening process, and this automatic process will reduce human interaction among the doctors and the patients. Thus, it acts as a safeguard to the medical imaging professionals and helps to reduce the spread of the virus. Furthermore, the computer-assisted AI-enabled automated classification and recommender systems support the radiologists to make clinical judgments, i.e., infection identification, tracing, projection with better accuracy, and efficiency [12].

The Reverse Transcription-Polymerase Chain Reaction (RT-PCR) test is typically used to measure the amount of any particular type of RNA. This RT-PCR is being used for the COVID-19 infection diagnosis [13]. However, the RT-PCR test has still some limitations. For example, as reported in [13], this powerful test produces high specificity, but the sensitivity from the test is very low (for example, as low as 59%). Therefore, the laboratory assessment suffers from inadequate sensitivity, which needs to be improved to enhance the performance further and for wider adoption.

To solve the aforementioned problem related to the false positive diagnosis, the latest AI-empowered tools and techniques need to contribute significantly toward building resiliency against the COVID-19 pandemic. The success of the AI-enabled tools are not only limited as a prototype these days, as a good number of commercial applications have also been introduced. Those applications incorporate the strengths of powerful deep learning and intelligent techniques to help slow down the spread and improved identification of the virus and thus exhibit technological competence against the spread of the pandemic [12].

In [14], the authors describe a process where deep transfer learning was used with Generative Adversarial Network (GAN) for COVID-19 recognition in X-ray images of a patient's chest. Ian Goodfellow introduced the Generative Adversarial Network (GAN) in 2014, which is a type of deep learning algorithm. GAN prototypes are mainly comprised of two networks, generative and discriminative network. The generator network is designed to generate new fake data instances, which are similar to training data. The purpose of the discriminator is to differentiate between actual data and fake data generated from a generator network. The generator network produces fake data to evade the network, and the discriminator network identifies the difference between actual and fake data and tries to prevent the evasion, which is the mission of the GAN models. The shortage of records regarding COVID-19 such as chest X-rays images is the key motivation for considering this type of model in [14]. The main idea of this GAN-based study is to gather all the available imaging data and COVID-19 test results and then utilize the GAN network to create more datasets to assist in the identification of the virus from the available X-rays scans with the maximum accuracy.

Another study [15] presents an early detection of COVID-19 using machine learning techniques, where the detection procedure was employed on CT scans of an abdomen. The experienced radiologists identified from CT scans that COVID-19 indicates dissimilar characteristics as compared to other viral pneumonia. Hence, the medical specialists can identify the COVİD-19 infection in the initial stage. For investigations regarding the identification of COVID-19, four dissimilar datasets were designed by considering patches with dimensions as 64 × 64, 48 × 48, 32 × 32 and 16 × 16 from a number of 150 CT scans. To improve the classification performance, a feature extraction process was applied to patches, which utilized algorithms such as Grey Level Co-occurrence Matrix (GLCM), Local Directional Pattern (LDP), Grey Level Run Length Matrix (GLRLM), Grey-Level Size Zone Matrix (GLSZM), and Discrete Wavelet Transform (DWT). Support Vector Machines (SVM) were used to categorize the extracted features. Ten-fold, 5-fold, and 2-fold cross-validations were applied throughout the categorization process. Precision, accuracy, specificity, sensitivity, and F-score metrics were utilized to assess the categorization performance. The best accuracies were achieved as 99.68% with 10-fold cross-validation and the GLSZM feature extraction technique.

It is obvious that an initial identification of COVID-19 is essential to slow down the spread of COVID-19 and avoid transmission by an early quarantine of victims as well as tracing and isolation of close acquaintances. For patients diagnosed with COVID-19, the precise monitoring of disease development is a vital element of disease administration. Medical imaging records such as chest X-ray and CT scans play a significant part in confirming the positive identification of COVID-19 disease as well as observing the evolution of the disease. These sorts of imaging data exhibit irregular distinctive patterns that emerge right after the COVID-19 infection starts. These anomalies peaked during 6th to 11th day of the illness. The next most predominant pattern of lung conditions anomalies peaks during the 12th to 17th day of the illness [16]. Computer-Aided Diagnosis (CAD) methods that integrate X-ray and CT scan results with deep learning algorithms can help physicians as identification aids for COVID-19 and assist further to provide a better understanding of the disease progression.

## 2.2. Patient Condition Monitoring Using Clinical Data

The patient's condition can be monitored remotely by taking a patient's status or clinical data through the remote monitoring technology [7]. These technologies can link wirelessly to the networks via WiFi, Bluetooth, or cellular connection. The same idea can be implemented for the monitoring of infectious diseases such as COVID-19. This distant observing technique can be utilized to screen persons exposed to COVID-19 as well as close acquaintances of the infected person. These technologies can also be applied to prevent the exposure of medical professionals to the high-risk patient populations. In principle, the same technological arrangements presently utilized by remote monitoring programs can also be utilized to incorporate a temperature measurement tool such as a smart thermometer for monitoring individuals that are suspected of having COVID-19 [7]. AI and ML can significantly help to improve monitoring and identify abnormal patterns or behaviors. ML and AI-based advanced data analytics and signal processing can help to filter the data and identify the patterns.

## 2.3. Drug Development, Selectio,n and Delivery

In [17], the authors use a drug–target interaction prototype titled as Molecule Transformer–DrugTarget Interaction (MT-DTI) that uses the deep learning method to identify drugs that are available in the market to react on viral proteins of SARS-COV-2. In another paper [18], the authors formulated a model that uses machine learning technology to forecast the potential inhibitory synthetic antibodies for SARS-COV-2 virus. They gathered antibody sequences of the 1933 virus and their clinical patient neutralization reaction and pre-trained a machine learning model to forecast the antibody reaction. Utilizing graphical representation with different ML techniques, the authors selected thousands of antibody sequences and found eight steady antibodies that hypothetically inhibit SARS-COV-2. The authors combined bioinformatics, structural biology, and Molecular Dynamics (MD) simulations to authenticate the constancy of the candidate antibodies that can inhibit the SARS-COV-2 virus.

Nowadays, we are observing rapid advancement in every aspect of science and technology, and it is also the same scenario in the sector of biological science, where complex biological data such as DNA structures and protein sequences are now available. With the help of machine learning techniques, those available data can predict complex biological scenario to analyze the virus protein structure and potential antibodies. With proper and sufficient training data, a machine learning mechanism can be utilized to create relations between the virus entity and reaction of its probable antibody. A pre-trained ML tool can predict potential antibodies for a given protein sequence of a virus faster than the human immune system, which can be very useful while combating against any pandemic such as COVID-19 and can save many lives in a timely manner.

According to another study [4], in China, one approach that was utilized to overcome the medicine delivery concerns during the epidemic was by employing an IoT-based service platform (Figure 3 exhibits the workflow). The platform created orders by automatically analyzing the information from historical records. Those orders may be modified and submitted by the pharmacists and then sent to the medicine suppliers from where the medicines are distributed within a specified time. This had lessened the spread of the disease during medicine purchase and also saved resources and labor cost.

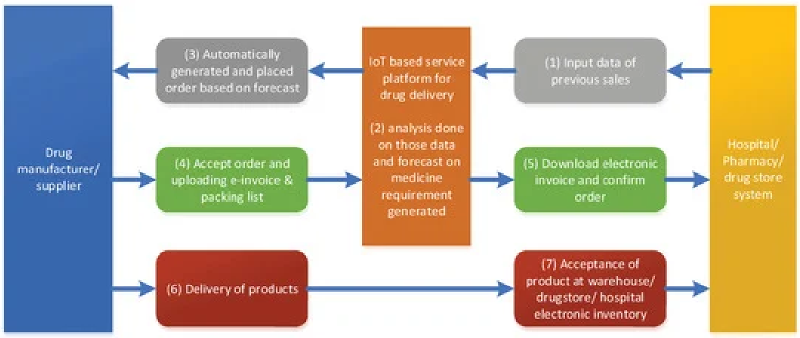


**Figure 3.** The Internet of Things (IoT)-based drug delivery system [4].

### 2.4. Virus Propagation Modeling and Prediction

The rapid spreading of the COVID-19 disease may be because of various reasons. One reason is the lack of information transparency at the initial phase of this pandemic outbreak. Sharing the pandemic-related information in a timely and precise way is tremendously vital for the anti-epidemic reaction of the community. The transparency in information sharing could have minimized the spread of this disease at the initial phase of the pandemic. Another reason is the unavailability of a proper systematic diagnosis standard for this virus. The prompt development of testing systems for a novel virus is very challenging. The symptoms of this virus are highly alike to symptoms of other less dangerous flu, which worsens the accuracy of diagnosis. Finally, due to the absence of a proper epidemic warning and prediction arrangement, we lost the chance to prohibit the spreading of this disease at the early phase.

In the current SARS-COV-2 transmission situation, the epidemiological study is tremendously essential for preventing the transmission by tracing the contagious trails and detecting the connection chains contributing to the rapid spreading. However, the outbreak of the COVID-19 was boosted up by the high movement of people during the most significant customary carnival of China, which worsened the transmission of the virus and at the same time greatly amplified the challenges of the epidemiological investigation [19]. It is vital to observe and predict the evolution of an epidemic while making decision against this kind of health crisis. In this situation, the mathematical propagation model has achieved more consideration and attention in terms of the epidemiological research. The Susceptible–Infected–Removed (SIR) model is one of those mathematical propagation models. The research on plague in the early 20$^{th}$ century introduced this SIR model. Remarkable development has been made in the mathematical propagation model of epidemiological research since the middle of the 20th century. At present, some important factors inducing the epidemic transmission were incorporated in the classic SIR model, such as the model taking into consideration the maturation phase, the SEIRS (Susceptible–Exposed–Infectious–Recovered–Susceptible) model taking into consideration the age of people and the population exposed to an epidemic and the Susceptible–Infectious–Susceptible (SIS) model including the birth and death of vulnerable patients. Some dynamical prototypes were planned to consider only specific disease analysis. For instance, the dynamical models were designed to simulate the spreading of human immunodeficiency virus (HIV), severe acute respiratory syndrome (SARS), and Middle East Respiratory Syndrome (MERS). With the advancement of innovative techniques, complex network theories and machine learning techniques were incorporated with the mathematical propagation model, which generated an effective method of epidemic prediction.

The construction of the SIR prototype for an epidemic analysis requires defining a number of vital parameters (such as the rate of infection and the rate of infection elimination) factually or statistically. The SIR prototype has established a complex model enabling a more detailed classification of individuals—for example, the exposed group and the protection group. As a matter of fact, the more accurate the prototype, the more chances are there that it can make an accurate forecast. However, for better accuracy, the model requires more realistic data to define additional factors. Alternately, some effort has also been made for developing a simplified prototype. For instance, the renowned logistic equation was used as the two sections ‘‘S-I’’ (Susceptible–Infectious) prototype, which can be additionally incorporated for some procedures in the modeling of SARS. The aforementioned studies demonstrate that the SIR-family prototypes can capture the base mechanism of the epidemic transmission at diverse complex stages quite well.

In one study [19], the authors tried to represent an initial forecast of the COVID-19 epidemic obtained from a basic SIR prototype. The justification of the obtained epidemiological information was investigated initially to achieve a realistic approximation of the fundamental factor, such as the rate of infection. Focusing on the rate of infection and the rate of disease elimination, a number of trials were planned to simulate the transmission of SARS-COV-2 virus under diverse stages of anti-epidemic measure and precautions. The forecasted infection intervals for the collective cases and the fading-out time of the epidemic are presented. The outcomes of the study are supposed to deliver vital statistics for crisis management against this COVID-19 pandemic.

## 2.5. Early Prediction or Detection of COVID-19 Syndromes

AI plays a significant role in identifying the collection of cases and forecasting the location where this disease will spread in the future by gathering and scrutinizing all previous data related to this outbreak. This technology can detect the disease characteristics and can predict its nature from the obtained information through social media and other digital or paper media platforms, regarding the possibilities of the contagion and potential nature of spreading. Additionally, it can predict the number of infected cases and death in any specific area based on related data and information [20].

In [21], the authors present a machine learning analysis of the COVID-19 pandemic based on the information of the initial phase of infection dynamics. The objective is to extract actionable insights for the improved understanding of community health. These understandings include the disease transmission probability, the rate at which mild infection transforms into a serious infection, asymptomatic approximations for infections, and forecasts of new infections over time.

In a study [22], the authors demonstrate the Bayesian Convolutional Neural Networks (BCNN), which is based on Monte-Carlo Dropout to determine the uncertainty in the methods of deep learning techniques that are used to improve the performance of the detection process while investigating chest X-ray reports of COVID-19 victims. They conclude that if the model is responsive about the system uncertainty, this method will improve the performance hugely and can facilitate the medical sector with a wider implementation of advanced technologies such as artificial intelligence.

In [23], the authors proposed a machine learning method-assisted SIR model to investigate the COVID-19 epidemic in a practical scenario. In this effort, they utilize the traditional Kermack–Mckendrick SIR prototype to describe the spreading pattern of the epidemic of COVID-19. The SIR prototype can model how an infection is transmitted over a population. In the research, they consider the total number of the population as a constant and classified them into different categories for more accuracy.

In [24], the authors utilize an effective approach to identify potential therapeutic molecules that combined machine learning technique and highly reliable docking simulation models. The researchers initially apply the screening plan to two drug datasets to discover a number of therapeutic molecules that have a strong bindness to the systems. The authors use the ML model to screen a huge number of bio-particle datasets to create a list of possibly beneficial composites with high rank and order for more confirmation. Overall, this effort will enhance the understanding of molecular treatment of COVID-19 and at the same time deliver an effective way of drug selection by merging high-performance machine learning prototypes with high-fidelity models for speeding up the therapeutic treatment of the diseases. A data-driven model trained with both data and first principles is proposed in [25]. The model can quickly be re-trained any time when new data become available.

## 2.6. Protecting Healthcare Workers

Most researchers have identified that artificial intelligence has brought an exemplary change in the medical sector and there might be value in the use of AI to the present COVID-19 epidemic, for instance, in forecasting the place of the next occurrence. As David Heymann (Assistant Director, WHO) headed the global response to SARS, he clarifies some vital factors that are essential for an effective public health response to an occurrence of a novel contamination. These factors include a consideration of transmissibility and vulnerable groups; forming the natural history of contamination, comprising the development period and death rate; recognizing and characterizing the underlying reasons; and, in some cases, epidemiological modeling to propose effective prevention and control measures [26]. These data can be gathered from those employed at epidemic locations virtually linked with the WHO. This approach functioned for SARS and is, again, a major source of information for COVID-19, as discussed by David Heymann. Finally, this information can be utilized to train and introduce the AI application for its dedicated task. The role of the healthcare professionals is important. They are not only helping to collect the COVID data but also helping the vulnerable patients in person, risking their own life. AI and ML can help identify the risk and also help automate a number of functionalities. Reflecting on a swiftly rising fear in the present epidemic that concerns the contamination of medical staff, Kuan Chen, founder of Infervision, points out that the AI application can assist in protecting the healthcare professionals [26]. Similarly, researchers and vendors are trying to utilize AI-enabled medical devices to reduce direct contact during SARS-COV-2 virus diagnosis and treatment.

## 2.7. AI-Enabled Self-Testing Framework

An AI-enabled self-testing framework is shown in Figure 4. The framework has three major phases. At the initial phase, the patient-side sensor devices will collect the specimen supplied by the patient. Based on the samples collected by the sensors, AI and ML-based analytics will be used for further processing. Decisions can be made locally in an edge node or could be in the cloud when compared with historical data if necessary. Finally, based on the test results, patients will be notified via mobile phone. To communicate among the peers, the blockchain-based framework could be very helpful. As the test results are very sensitive and require better security and privacy protection, blockchain may serve that purpose. Being a distributed ledger technology, the blockchain-based framework can be connected with local and international databases, while the AI-based decision-making process helps patients with self-diagnosis [27].

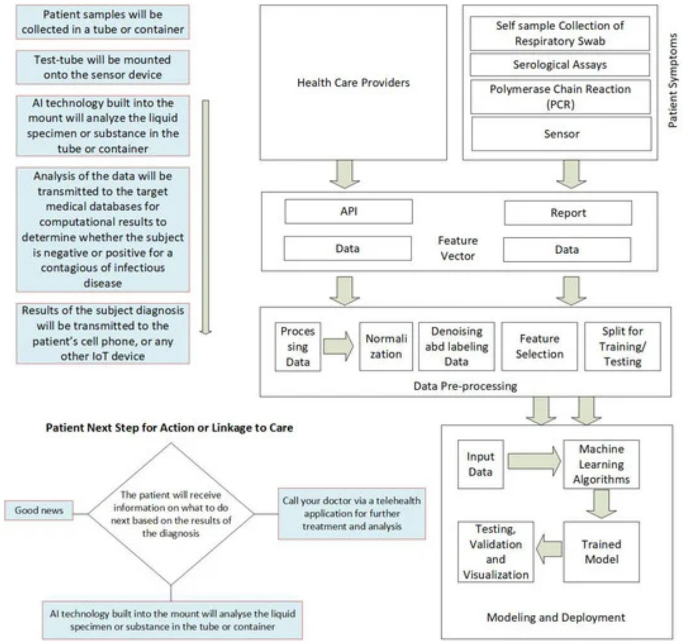


**Figure 4.** Artificial intelligence (AI)-enabled self-testing framework, adopted from [27].

Table 1 summarizes the articles and projects related to the AI applications toward improved resiliency against the COVID-19 pandemic.

**Table 1.** Summary of the research contributions considering artificial intelligence (AI) to mitigate COVID-19.

| Paper/Project Name | Reference No. | Domain | Contribution |
|---|---|---|---|
| Madurai Elavarasan, R. and Pugazhendhi, R. (2020). Restructured society and environment: A review on potential technological strategies to control the COVID-19 pandemic. | [4] | Drug development, selection, and delivery | Review of potential technologies such as AI, ML, and IoT in the healthcare sector for forecast of the epidemic, disease investigation, medicine delivery, etc. |
| Alwashmi, M. F. (2020). The Use of Digital Health in the Detection and Management of COVID-19. | [7] | Patient condition monitoring using clinical data | Review of outbreak response management and analysis system and remote monitoring technology for infected victims. |
| Shi, F., Wang, J., Shi, J., Wu, Z., Wang, Q., Tang, Z., Shen, D. (2020). Review of Artificial Intelligence Techniques in Imaging Data Acquisition, Segmentation and Diagnosis for COVID-19. | [12] | Medical Imaging for COVID-19 patients | Review of integration of artificial intelligence in imaging for detection, diagnostics, and tracing the spread of the epidemic. |

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| Meng Li. Review: Chest CT features and their role in COVID-19. Radiology of Infectious Diseases, www.sciencedirect.com | [13] | Medical Imaging for COVID-19 patients | Review of COVID-19 disease detection by imaging tools such as CT scans. |
| Mohamed Loey, Florentin Smarandache and Nour Eldeen M. Khalifa. Within the Lack of Chest COVID-19 X-ray Dataset: A Novel Detection Model Based on GAN and Deep Transfer Learning. | [14] | Medical Imaging for COVID-19 patients | Describes a deep learning process that used Generative Adversarial Network (GAN) for COVID-19 investigation in chest X-ray images of patients. |
| Mucahid Barstugan, Umut Ozkaya, Saban Ozturk. "Coronavirus (COVID-19) Classification using CT Images by Machine Learning Methods". | [15] | Medical Imaging for COVID-19 patients | Describes the implementation of the machine learning technique in the process of COVID-19 disease detection. |
| Sara Hosseinzadeh Kassania, Peyman Hosseinzadeh Kassasnib, Michal J. Wesolowskic, Kevin A. Schneidera, Ralph Deters. "Automatic Detection of Coronavirus Disease (COVID-19) in X-ray and CT Images: A Machine Learning Based Approach". | [16] | Medical Imaging for COVID-19 patients | Reviews the implementation of machine learning methods to identify COVID-19 disease in medical images. |
| Beck, B. R., Shin, B., Choi, Y., Park, S., and Kang, K. (2020). Predicting commercially available antiviral drugs that may act on the novel coronavirus (SARS-CoV-2) through a drug–target interaction deep learning model. | [17] | Drug development, selection, and delivery | Implementation of a deep learning method to identify potential medicine against COVID-19 disease among commercially available medicine. |
| Rishikesh Magar, Prakarsh Yadav and Amir Barati Farimani. "Potential Neutralizing Antibodies Discovered for Novel Corona Virus Using Machine Learning." | [18] | Drug development, selection, and delivery | Application of artificial intelligence to forecast potential antibodies against SARS-COV-2 virus. |
| Zhong, L., Mu, L., Li, J., Wang, J., Yin, Z., and Liu, D. (2020). Early Prediction of the 2019 Novel Coronavirus Outbreak in the Mainland China based on a Simple Mathematical Model. | [19] | Virus propagation modeling and prediction | Describes early prediction of COVID-19 epidemic based on SIR epidemic prediction model. |
| Vaishya, R., Javaid, M., Khan, I. H., and Haleem, A. (2020). Artificial Intelligence (AI) applications for COVID-19 pandemic. | [20] | Early prediction or detection of COVID-19 syndromes | Review of the application of artificial intelligence technologies in prediction of COVID-19 spreading. |
| Malik Magdon-Ismail. "Machine Learning the Phenomenology of COVID-19 From Early Infection Dynamics". | [21] | Early prediction or detection of COVID-19 syndromes | Present implementation of machine learning analysis on COVID-19 epidemical statistics to forecast disease transmission. |

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|---|---|---|---|
| Biraja Ghoshal and Allan Tucker. "Estimating Uncertainty and Interpretability in Deep Learning for Coronavirus (COVID-19) Detection". | [22] | Early prediction or detection of COVID-19 syndromes | Demonstration of Monte-Carlo Dropweight-based Bayesian Convolutional Neural Networks method to improve the performance of COVID-19 detection process. |
| Babacar Mbaye Ndiaye, Lena Tendeng, Diaraf Seck. "Analysis of the COVID-19 pandemic by SIR model and machine learning techniques for forecasting". | [23] | Early prediction or detection of COVID-19 syndromes | Proposes an SIR model supported by machine learning to investigate the epidemic in the real world. |
| Rohit Batra, Henry Chan, Ganesh Kamath, Rampi Ramprasad, Mathew J. Cherukara, and Subramanian Sankaranarayanan. "Screening of Therapeutic Agents for COVID-19 using Machine Learning and Ensemble Docking Simulations". | [24] | Early prediction or detection of COVID-19 syndromes | Proposes the utilization of a machine learning and docking simulation model to identify therapeutic molecules. |
| Luca Magri and Nguyen Anh Khoa Doan. "First-principles machine learning modelling of COVID-19". | [25] | Early prediction or detection of COVID-19 syndromes | Proposes a data-driven model that is trained with both data and first principles on an epidemiological model. |
| Becky McCall. "COVID-19 and artificial intelligence: protecting health-care workers and curbing the spread". | [26] | Protecting healthcare workers | Review of artificial intelligence application in protecting healthcare professionals. |

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