Integration of Deep Learning Machine Models with Conventional Diagnostic Tools in Medical Image Analysis for Detection and Diagnosis of Novel Coronavirus (COVID-19)

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Abstract Novel coronavirus 19 (COVID-19) had made the lives of humans in dilemma since its outburst from Wuhan, China on December 31, 2019, and is declared as a pandemic by the World Health Organization (WHO). Its spread had been very rapid among the people which is a real task for the authorities to identify the persons infected with viruses and isolate them to prevent virus transmission. At present, various diagnostic aids are used in health care centres to screen the public with the symptoms of COVID-19. However, the use of conventional medical aids is of no use in early detection because of the rapid transmission rate. Therefore, researches are exploring Artificial Intelligence (AI) incorporated techniques that will aid physicians in the early detection of COVID-19 and one such method is Deep Learning Machine Models (DLM). This chapter aims to review research studies available in PubMed database with the Keywords COVID-19, Diagnosis, Deep learning models, and Medical Imaging till August 10, 2020 related to COVID-19 and DLM in medical image analysis. By evaluating 13 full text articles we calculated F1 scores for possible studies and concluded that studies with Computed Tomography (CT) had better diagnostic accuracy when compared to chest X-ray (CXR).

Keywords Artificial intelligence · COVID-19 · Deep learning machine models (DLM) · Diagnostic aids · Early screening
1 Introduction

In December 2019 Wuhan provenance many people were infected with symptoms of fever, cough, and shortness of breath and are represented as severe unexplained pneumonia. Later this spread to many countries made the situation worse and resulted in deaths. In February 2020 World Health Organization (WHO) declared this condition as a pandemic and named the new virus as Novel Coronavirus 2019 (COVID-19) [1]. As there are no approved drugs in use for this new virus only treatment option is to reduce the disease severity with the existing drugs like Chloroquine, Remdesivir, and Fapilavir, etc. The prevention and control model for this pandemic is mentioned in Fig. 1:

1. Early detection, reporting, and isolation of infected persons.
2. Providing adequate necessary resources to all infected patients.
3. Hospitalize all the suspected and virus-positive patients.

As per Fig. 1, the biggest worry is the early detection, reporting, and isolation of the infected patients. Because the virus is spreading at a rapid pace so that existing medical facilities and medical aids are not enough to perform adequate viral testing. According to Liu et al. the virus, basic reproduction number (R0) is determined to be 2–3 which is high when compared to the Severe Acute Respiratory Syndrome Virus (SARS) [2]. Due to its high transmission rate existing medical tools like Computed Tomography (CT), reverse transcription-polymerase chain reaction (RT-PCR), X-ray, and sputum test, etc. are not enough for early detection of COVID-19 cases also sometimes false negatives are being resulted. So researches

![Fig. 1 Illustration of the prevention model for control of corona pandemic](image-url)
are looking at advanced technologies like Artificial Intelligence to incorporate into diagnostic aids for rapid detection of viral screening. One of such techniques is Deep Learning Machine models (DLM) is a technique of AI that teaches computers to perform what naturally comes to humans. DLM is also used in areas like agriculture, mobile, and wireless networking, Internet of things, bio-informatics, and health management systems. One such application more frequent in use during the COVID-19 pandemic is lung image analysis models of corona infected patients. Because they will automate the characteristics of the symptoms of COVID-19 and also able to distinguish between the non-COVID-19 and COVID-19 persons in a very quick time. DLM performs various tasks such as classification, clustering, regression, image reconstruction, lesion detection, and segmentation. All these functions are performed by the development of paradigms like:

1. Support Vector Machine
2. Random forest
3. Backpropagation network
4. Neuro-fuzzy inference systems
5. Convolutional neural networks [3].

Normally interpretation of X-rays needs technical skill and also time taking. So radiologists use a deep learning model that will automate the analysis of X-rays and reduce the time taking for interpretation and speed up the diagnostic process. Here a group of X-rays is analyzed by the use of a Machine learning model which is equipped with all the necessary sets of instructions to perform its functions. After the analysis of images by the machine learning programs, these are evaluated by the radiologist to provide the final diagnosis [4].

2 Role of Medical Imaging in COVID-19 Detection

Basically, the techniques used in the detection and diagnosis of COVID-19 are Computed Tomography (CT), reverse transcription-polymerase chain reaction (RT-PCR), X-ray, and sputum test. Of these techniques, the use of CT is controversial because it cannot able to diagnose the patients with COVID-19 and other lung-related problems especially pneumonia. Therefore, radiological societies did not recommend CT as a screening tool for the detection of COVID-19. But the study of Simpson et al. predicted the use of CT screening as a tool for the diagnosis of COVID-19 and reported four categories of CT findings related to the COVID-19 [5]. A study of Mahmood et al. that included 12,270 patients reported that CT had gain both sensitivity and specificity and can be used as a screening tool for the detection of COVID-19 patients at the earliest and prevent the spread of infection [6]. In the study of Pereira et al. reported the chest X-ray (CXR) is cheaper, easier, and universal [7]. In yet another study by Dong et al. reported that CT scans can improve the accuracy of diagnosis, detection, and management of COVID-19
condition based on the clinical symptoms of patients [8]. The summary of these studies is represented in Table 1.

3 Materials, Methods and Procedure

3.1 Creating a Systematic Search Strategy

a. Constructing an appropriate question
b. Using the appropriate database(s)
c. Advanced searching in PubMed—MeSH terms and the MeSH database.

PICO (Patients, Intervention, Comparator, Outcomes) table for designing our question as shown in Table 2.

The Table 3 below provides brief descriptions of common databases and sources to search both peer-reviewed and grey literature.

PubMed database was screened with the Keywords COVID-19, Diagnosis, Deep learning models, and Medical Imaging till August 10, 2020. Title and abstract screening were done manually as there are very few articles. Full texts of these screened articles were further screened for possible inclusion and exclusion criteria. Totally 26 studies are obtained of these 13 falls into the category of deep machine

| Study         | Modality          | Targeted region | Application | Findings                                                                 |
|---------------|-------------------|-----------------|-------------|--------------------------------------------------------------------------|
| Simpson et al. [5] | CT                | Lung            | Diagnosis   | CT scan can detect COVID-19 pneumonia and their clinical features         |
| Mahmood et al. [6] | CT                | Lung            | Diagnosis   | CT can be useful as a screening tool without any delay of results when compared to serum assay, CRP, RT-PCR |
| Pereira et al. [7]   | CXR               | Lung            | Diagnosis   | CXR can able to identify the COVID-19 pneumonia cases from other pneumonia-causing pathogens |
| Dong et al. [8]       | Various imaging technologies like CT, CXR, RT-PCR | –               | Diagnosis   | The Combined use of AI&CT imaging is useful in the rapid diagnosis and prediction of COVID-19 |
learning and medical imaging were included. We excluded studies of preprints, Un-authored proofs, case studies, Fuzzy systems, Internet of things, and Robotic learnings. The flowchart of the study is shown in Fig. 2.
4 Research Studies Related to DLM Applications in COVID-19

In the study of Yu et al., they classified the subjects into two groups like 246 severe cases and 483 non-severe cases by using the four pre-trained deep neural networks and chest CT as a tool for the rapid, accurate, automatic tool for screening and follow-up of COVID-19 patients. Their results demonstrated that DenseNet-210 had high accuracy, sensitivity, and specificity for the detection of COVID-19 [9]. Another study of Masot et al. they categorized subjects as 316 training sets and 80 test sets for the identification of pneumonia and COVID-19 using the torso radiographs, VGG 16 based deep learning model. Their results found that VGG 16 based deep learning model had resulted in better sensitivity (0.92%) and specificity (0.85%) [10]. Another study of Mei et al. they categorized the subjects into two groups as positive SARS-Cov-2 and Negative SARS-Cov-2 for the improved detection of patient diagnosis by using three deep learning models. Their findings demonstrated that the Joint model (model 3) had a more specificity of 0.92% when compared to the other two models [11]. In the study of Li et al. they grouped the patients into three categories as COVID-19, Community-acquired Pneumonia, and non-pneumonia to develop an automatic and accurate detection of COVID-19 from other pulmonary diseases by using the COVNet as a deep learning model. Their results demonstrated that it has better sensitivity (90%) and specificity (96%) for COVID-19 [12]. Harman et al. used a deep learning algorithm for the detection of COVID-19 by using the chest X-rays of patients with both COVID-19 and COVID-19 pneumonia. His study proved that DLM has good accuracy (90.8%), Sensitivity (84%), and Specificity (93%) [13]. Another study of Apostolopoulos and Mpesiana used the Convolutional Neuronal Network models (CNN) to distinguish the X-ray images of common pneumonia, COVID-19, and Non-COVID-19 images. Their study demonstrated the accuracy of 97.82% in the detection of COVID-19 cases with the use of CNN [14]. Another study of Ko et al. demonstrated that the ResNet-50 model has the highest accuracy of 96.97% in the detection of COVID-19 pneumonia [15]. The study of Hurt et al. used the image modality CXR to identify the COVID-19 and pneumonia cases separately using the U-Net model. Their study reported the CXR had better robustness [16]. Study findings of Singh et al. reported the CT scan classifies the COVID-19 positive cases and negative cases accurately using the CNN algorithm [17]. Study findings of Yoo et al. reported that CXR can detect the COVID-19 and other pneumonia diseases with an accuracy of 98% by using the CNN model of deep learning [18]. Another study of Ni et al. used the modality CT of 96 patients integrated with MVP-Net and reported that its results are better when compared to the residential radiologists [19]. Another finding of Rajaraman et al. used the CXR of four different datasets and evaluated the performance of pruned models accuracy as 99% [20]. Findings of Brunese et al. proved that CXR integrated with the VGG-16 algorithm can able to distinguish the health X-rays, Pulmonary disease X-rays, and COVID-19 X-rays [21]. The summary of these studies is represented in Table 4.
| Study           | Modality | Subjects                                                                 | Task                                                                 | Methods                                                                 | Result                      |
|----------------|----------|--------------------------------------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------|
| Yu et al. [9]  | Chest CT | 246 severe cases 483 non-severe cases                                     | Rapid, Accurate automatic tool for severity screening follow up of COVID-19 | Deep neural network methods 1. Inception-V3 2. ResNet-50 3. ResNet-101 4. DenseNet-201 | DenseNet-210 95.20 Accuracy% 91.87% sensitivity 96.87% specificity |
| Masot et al. [10] | X-ray    | Training set-316 Test set-80                                              | Identification of pneumonia and COVID-19 using torso radiographs     | VGG16-Based deep learning model                                          | 0.92% sensitivity 0.85% specificity |
| Mei et al. [11] | CT       | 419-Positive COVID-19 cases 486-Negative for COVID-19                    | Improved detection of patients either positive or negative by using AI model | 1. Convolutional Neuronal network 2. Machine learning classifiers 3. Joint model | 0.86% specificity 0.80 specificity 0.92 specificity |
| Li et al. [12]  | CT       | 1296-COVID-19 1375-Community-Acquired Pneumonia 1325-non- pneumonia       | Detection of COVID-19 from community-acquired pneumonia and other lung diseases | COVNet                                                                   | 90% sensitivity 96% specificity |
| Harmon et al. [13] | CT     | 2167 patients both COVID-19 and COVID-19 pneumonia                        | Evaluate an AI algorithm for detection of COVID-19 on chest CT        | Deep learning algorithm                                                   | 90.8% Accuracy 84% Sensitivity 93% Specificity |
| Study                        | Modality | Subjects                                                                 | Task                                      | Methods                  | Result                                      |
|------------------------------|----------|---------------------------------------------------------------------------|-------------------------------------------|--------------------------|---------------------------------------------|
| Apostolopoulos and Mpesiana  | X-ray    | 224 images of positive COVID-19 patients. 700 images of common pneumonia. 504 images of Normal conditions. | Evaluation of performance and state of art of CNN model | Transfer learning       | 97.82% Accurate                             |
| Ko et al. [15]               | CT       | 3993 images of chest CT was used                                          | To develop a fast track COVID-19 network to diagnose COVID-19 pneumonia | 2D deep learning framework | ResNet-50 model highest accuracy of 96.97% |
| Hurt et al. [16]             | CXR      | 5 patients                                                                | To identify the COVID-19 and pneumonia cases separately | U-Net                    | CXR augment the generalizability and robustness of DL |
| Singh et al. [17]            | CT       | Datasets were used                                                        | Classification of COVID-19 positive cases and COVID-19 negative cases | CNN                      | CT performed better results in the differentiation of negative and positive cases of COVID-19 |
| Yoo et al. [18]              | CXR      | Datasets were used                                                        | Detect COVID-19, tuberculosis, normal images of CXR | CNN                      | 98% accuracy (Normal vs. Abnormal data) 80% accuracy (TB vs. non-TB data) |
| Ni et al. [19]               | CT       | 96 patients                                                               | Detect COVID-19 pneumonia on CT images   | MVP-Net                  | Algorithm -based findings showed better results compared to residential radiologists |
| Rajaraman et al. [20]        | CXR      | Datasets were used                                                        | Evaluate the performance of pruned models | Pruned deep learning     | 99% accuracy AUC 0.9972%                   |
| Brunese et al. [21]          | CXR      | 6523 images                                                               | Distinguish between healthy, pulmonary disease X rays, COVID-19 X-rays | VGG-16                   | 0.96% accuracy for healthy and pulmonary disease patients 0.98% accuracy for COVID-19 diagnosis |
All the studies related to the deep learning models that measure the study weightage are based on these important parameters:

1. AUC (Area Under the receiver operating Characteristic Curve)
2. Accuracy
3. Sensitivity
4. Specificity
5. F1-Score.

5 Discussion

The outbreak of the virus from the Wuhan had made the lives of people pathetic. Existing drugs and diagnostic aids do not cope up with the virus because of rapid spread across the world. Some reports stated the whatever the nucleic acid testing more used in the diagnosis of COVID-19 had an accuracy of about 30–50%. So Governments and Health care organizations advised the CT scans to analyze the pulmonary symptoms of the COVID-19 patients to detect false positives and false negatives accurately.

In this review, we analyzed 13 studies in which they used medical images and datasets of patients to detect the COVID-19 by the integration of deep learning models. F1 score was calculated by using a fx solver a mathematical guide. To conclude the best out of all these studies we calculated F1 scores for 7 studies that included CT or CXR as a diagnostic tool as shown in the Table 5. We could not calculate the F1 scores for the other six studies because the datasets of both the COVID-19 positive and COVID-19 negative patients were represented as a whole. F1 scores are calculated by using the formula

\[ F_1 = 2 \cdot \frac{p \cdot r}{p + r} \]

Here

\[ p = \text{precision} \]
\[ r = \text{recall} \]

| No. | Study         | F1 score |
|-----|---------------|----------|
| 1   | Harmon et al. | 0.1569   |
| 2   | Hurt et al.   | 0.1324   |
| 3   | Li et al.     | 0.3243   |
| 4   | Yu et al.     | 0.3374   |
| 5   | Mei et al.    | 0.4630   |
| 6   | Masot et al.  | 0.7980   |
| 7   | Ni et al.     | 0.9792   |
5.1 Interpretation

When the F1 scores had point 1 then the study had provided better results. If the F1 score is 0 score, then the study had achieved the poor results.

Of all the included studies to calculate the F1 score, the highest scores were obtained for the study of Ni et al. (0.9792) that was very close to the 1 followed by other studies. Therefore, this review suggested that calculation of F1 scores would provide the more suitable metrics for the accuracy of studies that used the DLM in medical image analysis. Our study findings suggest that use of CT serves better in early detection of COVID-19 when compared to CXR as a diagnostic aid. Therefore, the applicability of CT integrated with DLM as a better diagnostic aid to detect and diagnosis the COVID-19 must be addressed with further research studies.

6 Advantages of DLM Applications

1. Rapid screening
2. Segmentation
3. Detection and
4. Classification.

6.1 Rapid Screening

The use of the artificial intelligence or its related DLM models is pre-trained and integrates with the mathematical models for the processing and analysis of images automatically without any manual help hence the radiologists finds it easier to interpret the images. This can also minimize the time required for screening and also improve the accuracy of detection when compared to the manual image analysis. Therefore, more number of medical images are screened within less time.

6.2 Segmentation

Segmentation is a process of the partitioning of a digital image into multiple segments such as pixels and segments. So that the segmented portions are very easy to analyze. A study of Butt et al. proposed a 3D CNN to segregate many cubes from the CT scan. After the segmentation, it can classify the images into COVID-19 patches, Viral pneumonia images, and other related infections. Their study also achieved a sensitivity of 98.2% and specificity of 92.2% for COVID-19 cases and non-COVID-19 cases [22].
6.3 Detection

Detection is a process associated with a computer vision and can relate to the system that can recognize the presence of the desired object within an image. A study of Hurt et al. proposed a localization system of U-Net trained with 22k medical images that could be interpreted by radiologists for producing the maps of probability. This phenomenon can be applied to the patients of COVID-19 for the detection of images [15].

6.4 Classification

This is a type of supervised learning and can able to identify the specific class to which the data elements belong to. This process was used by Wu et al. and proposed a study about COVID-19 patients. They used the deep learning network models for the fusion of lung images in different views like axial, coronal, and sagittal views and can able to identify the medical images of COVID-19 patients.

7 AI Used Techniques to Prevent the Spread of COVID-19

As per Fig. 3, AI is not only useful in the control of COVID-19 but also it can be useful through indirectly as a Monitoring technology where we can estimate the economic burden facing by the country in these pandemic situations by satellite systems. As COVID-19 is spreading rapidly to people, treating physicians, and health care workers we are now exploring alternate options to look after the needs of infected patients. One such attempt is bringing ROBOTS in hospitals where they can look over the needs of patients. These robots are fixed by AI-based manual programs that an actual human can perform. Another application is the implementation of various AI-based social networking sites like Chatbots. Ex. Canadas COVID-19 Chatbot. These apps can itself diagnose and advise the public depending upon the symptoms and any need to visit the hospital. They can also able to identify the nearby COVID-19 cases in the surroundings within a specific distance. We can also able to calculate the risk of the patient by using the EpiRisk. This requires entering the symptoms of a person and calculating the probability of getting a disease. By the use of technology like social media we can suggest the public regarding the spread of COVID-19 and its precaution measures. This was similar to a study conducted by Arpaci et al. They analyzed the 43 million twitter tweets between March 22 and March 30, 2020 and reported that social media posts may affect human psychology and behavior and can assist the public in decision making and task prioritizing [23]. This can also be used as a platform for the government to communicate easily with the public to prevent the spread of COVID-19.


8 Limitations

1. Many of the countries are still at the initial stages of implementing AI-based approaches to combat COVID-19 because of various factors like resources, technology, budget for implementation etc.

2. Another thing that must be mentioned is the size of data sets. Normally if the data or the subjects involved in the study are more we can estimate the results very accurately and precisely but in contrast to this whatever the data sets are available in the healthcare settings are too small to estimate the results accurately.

3. Regulatory approval for the DLM techniques is quite challenging and is poorly addressed currently but it is very important for the healthcare settings to get the regulatory approval to establish the quality assurance and robustness of the study.

9 Conclusion

Existing drugs and treatment options are not in a position to counteract the virus where they can only act as a symptom normalizer. So we need a different approach like AI and advanced technology for early identification of vaccines and to identify the lead molecules. Machine learning is more frequently used in medical settings and recently techniques like DLM are predominant. This review concluded that F1

Fig. 3 Various techniques of AI to prevent the spread of COVID-19
scores is the accurate measure to estimate the results of study in an efficient manner and CT integrated with DLM models had provided better diagnostic accuracy when compared to X-rays for the detection of COVID-19.

In this chapter, we presented advances in deep learning models in healthcare to combat the COVID-19 are useful for the radiologists as a diagnostic tool to identify the accurate cause with diagnosis to avoid false negatives and false positives and detect the positive cases within less time. Hence we motivate to use the deep learning models instead of the traditional machine learning to address the significant problems efficiently.

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