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The Role of Artificial Intelligence Based Models in The Diagnosis of Covid-19 On Computed Tomography-A Systematic Review

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Abstract
The main objective of this study is to emphasize the role of Artificial Intelligence based models in the diagnosis, differentiation, evaluation of the severity of COVID-19 while utilizing CT as imaging modality AI based models. **This review was according to guidelines of the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA).** Fifteen articles were reviewed for the evaluation of the results of AI based models in diagnosis and in assessment of the severity of COVID-19. The presented models shows higher accuracy, sensitivity and specificity. The presented models diagnosis the virus in rapid way and it also reduces the workload on radiologists. The models are categorized in differentiating the patients with normal person from COVID-19, other pneumonia and the affected part of lungs by COVID-19.Various tests are performed for the robustness of these models, and the comparison of the AI based models results with experienced radiologists that makes them more useful and accurate in diagnostic **approach.** COVID-19 is continuously spreading across the World. Advanced classifying and diagnostic models for COVID-19 based on AI are widely available and proved favorable in the diagnosis of COVID-19. The models based on "deep learning" "machine learning" "multiple instance learning" and "transfer learning" are available for the diagnosis of this disease and differentiating it from others pneumonia.The sensitivities and the specificities are greater than 85%, which makes them a valuable tool for diagnosis.By improving the geographical information and number of patients for the training, can make these models very fast diagnostic tools for COVID-19**.**

Keywords: COVID-19, Computed Tomography, Artificial Intelligence.

Introduction

It was the time of December 2019, when unknown manifestations of pneumonia were reported in Wuhan city of China. The Centre of disease controlling China declared it the novel Corona viral pneumonia which have origination from the newly introduced virus of its family.[1] World Health Organization gives the name SARS-CoV-2 to the virus and COVID-19 to disease on 11 February 2020.[2] WHO announces this outbreak a public health emergency of international concerns on January 30,2020 and a pandemic on 11 March 2020.[3]Corona-virus belongs to the family of RNA viruses their genomic sequence is in between 25-35kb, having four kinds of proteins namely, Structural, Envelope, Membrane and Nucleocapsid proteins.The corona viruses are arranged in the family of Coronaviridae because of having halo or crown like presentation that is because of the glycoprotein-studded enveloped presentation on electron microscope.[4]Corona-virus affects both mammals and birds, bat is the host for this virus where it is non-infectious. In this way bat is the host despite of affecting from it.[5]The diagnostic approach to COVID-19 is broadly categorized into "laboratory-based approach" which includes the point of care testing, the nucleic acid testing, antigen antibody-based tests, and serological tests) and "Medical imaging diagnostic tools" (comprises of X-rays, Computed Tomography and Ultrasonography). Laboratory based tests takes samples through nasopharyngeal swab, the throat swabs, sputum based, and the deep airway material. Among these, nasopharyngeal swab method is most common, and involves exhibiting a swab to paper strips having artificially designed antibodies for the attachment of corona-virus antigens.The attachment of antigens to strips allows a visual readout. This is very fast and easy method. But the sensitivity of nucleic acid test is in between 60-71%.[5]The medical imaging is the second way in the detection of virus. These imaging modalities are playing key role in the management of patients and in managing the suspected ones. This is noteworthy that the clinical correlation is very important because findings from x-rays and CT images have very similar patterns as of other diseases.[5]Chest CT is the imaging modality of choice having sensitivity of about 97.2% which makes CT a primary tool for the diagnostic purpose of COVID-19.[6]Chest CT involves the transmission of x-rays through the chest and detection of these radiations by the detectors incorporated in it and the reconstruction of acquired images into images of higher quality.[7] The potential findings include Ground-Glass opacities, crazy-paving consolidation, air bronchogram reverse halo and peri lobular pattern.[8]The exponential increase in patients and increased workload in Computed Tomography department for diagnosis with the limited availability of experienced radiologists was challenging.Artificial intelligence (AI) is employing its part for the management of virus by tracking the spread, predicting the patients at higher risk. Mortality rate can also be anticipated by inspecting the data of victims. AI also assists the fight against COVID-19 by continuous screening of individuals and notifying about the current situation.[9]Since its inception AI has proved very useful in medical applications, and it has wide acceptance because of its higher accuracy and prediction values.There are various classification and segmentation algorithms in conjunction with AI technology.These algorithms attain higher performance in against the human experts because of to its limited working time and higher accuracy.[10]Studies shows that AI can accurately detect COVID-19 and it can also differentiate it with other lung diseases and community acquired pneumonia.This paper is reviewing the role of AI based models in the diagnosis of COVID-19 by utilizing Computed Tomography as imaging modality.

Materials and Methods

This review was according to guidelines of the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA).

Search Strategy

This literature review research was performed with the help of following search engines: PubMed, Google Scholar, Elsevier, Research Gate and Medscape, the key words and abbreviations were: “SARS-CoV-2”, “COVID-19”,“Coronavirus Disease”,“Artificial Intelligence”,“Pneumonia”,“AI based models for the COVID-19 diagnosis”,“imaging pattern while using the Artificial Intelligence”.

Inclusion Criteria

(a) Computed Tomography based Artificial Intelligence models for the diagnosis of COVID-19
(b) Patients Suffers from pneumonia and clinically suspected for COVID-19
(c) RT-PCR and CT COVID-19 confirmed patients
(d) Thoracic CT features showing pneumonia
(e) Studies related to SARS, MERS, bacterial and Viral pneumonia’s comparison with COVId-19 and all articles that were published in English language.

Exclusion Criteria

Letters to editorials, comments, case reports, and studies with less than 10 patients were excluded.

Data Collection

Articles were evaluated in accordance with the above mentioned keywords that are part of title and abstract. The studies that are not coinciding with the explained criteria were excluded.By removing the replica articles, secondary screening was accomplished to find the compatible articles for diagnosis of COVID-19, by using AI trained models on Computed Tomography.

Data extraction

Data is extracts from the journal eligibility criteria for articles and articles are concluded on the basis on their applicability and quality.The Statistical analysis are performed by using raw data used in the studies.The Numerical values are from the results, material and methods, tables and figures.

Data Synthesis and Analysis procedure

The 15 included articles are mainly used in data extraction. Data is withdrawal on basis of : Authors, its publication year , total patients, duration of Computed Tomographic scan performing, AI, models trained on AI, DCNN, machine learning based models, Deep learning-based, Multiple Instance learning models, Covid-19, pneumonia, cross validation protocols, SARS-Cov-2 pneumonia, Bacterial Pneumonia, Viral Pneumonia, Convolutional Neural Network, Classification models, diagnostic models, differentiating models and severity assessment models.

Results

Our Primary literature searched total forty eight (48) articles.Thirteen (13) articles removed because of replication.Thirty five (35) studies were screened for title and abstract.Twenty (20) articles were excluded not containing required information.Fifteen (15) articles were included related to computed tomography images and artificial intelligence used to detect COVID-19. Figure 1.1 showed whole process of the literature search and data analysis. Table 1.2 showed the qualitative variables (Author name, publication year, number of patients, AI model used, sensitivity, specificity, accuracy and AUC) of 15-screened studies.

COVID-19/Normal Classification Studies:

AI based model; Deep transfer learning model (DLT) proposed by Aayush Jaiswal et al, it was trained on DenseNet201.The data was acquired from 2492 Computed Tomography scans, 1262 were of COVID-19 and 1230 were non-COVID-19.They developed a novel deep transfer learning model which was designed on Convolution Neural Network (CNN) and the pre-formed DenseNet201 model.This was designed for the extraction of COVID-19 features against the non-COVID-19 by utilizing their predefined learned weights on the ImageNet dataset along the CNN structure.They also hypothesized that with limited data availability, the result of transfer learning was remarkable and the hyper-tuning of model also enhances the accuracy.The accuracy of this model was 96.25%, sensitivity of 96.29% and specificity of 96.21%.Runwen Hu et al. collected the data from 1042 individuals, of them 521 were COVID-19 affected, 397 were healthy, 76 were bacterial pneumonia and 48 were severe acute respiratory syndrome patients to construct a model on ShuffleNet V2 network.The reason to develop the model on ShuffleNet V2 network is its higher accuracy and higher speed to run. After applying the crop operation, data was fed to ShuffleNet V2 network and then the results were extract from them.The probability score for diagnosis were obtains on sending the data to linear layer.They divided the data into the training set, the validation set and the testing set.It also includes the sixteen data augmentation operations to compliment the training phase.The specificity of this model was 91.58%, sensitivity of 90.52% and accuracy of 91.21%.Md Zahangir Alom et al. proposed two models namely, Inception Recurrent Residual Neural Network (IRRCNN) and NABLA-N respectively.Both these were based on Transfer Learning (TL).They take 420 samples of them 178 were COVID-19 pneumonia and remaining 247 were normal persons. IRRCNN model was comprised of an input layer, five IRRUs layers, a Global Average Pooling (GAP) layer and the Softmax output layer.The NABLA-N were based on an encoding and a decoding unit.IRRCNN was trained and tested on the pneumonic patients.The accuracy of detection by using this model was 98.78% and the accuracy of segmentation was 99.56% in these models.

Diagnosis of COVID-19 studies:

Quan Zhang et al. conducted a retrospective study and proposed Generative Adversarial Residual Convolution Diagnosis (GARCD).They utilized 14,129 chest HRCT images from 61 patients affected with COVID-19 and 43 were normal. GARCD were further comprised of two modules the GA or Generative Adversarial Network and Residual Convolutional Network (RCD).GA was built for the enhancement of the image quality by modifying the semantic features, thus GA was for the repairing of low-quality images. RCD was diagnostic module and based on residual convolutional layers.The sensitivity of their model was 96.97% and specificity of 91.16%.A model dual-branch combination network (DCN) was trained by Kai Gao et al. for quick diagnosis of COVID-19.Model is designed for the classification and segmentation of affected areas of lungs. They collected data from 704 COVID-19 positive and 498 normal individuals.The backbone of classification model was ResNet50 and segmentation part was built on U-net and it comprised of the encoder and a decoder.The entire model was categorized into three parts. Part 1 as the lung segmentation network, which extracts the affected area of lung. Part 2 was the proposed DCN model, it was executing the simultaneous classification and segmentation of computed tomographic images with suggested Lesion attention module.Part 3 comprised of the results of image slices that were integrated with the help of probability mapping score method for attaining the classification results in an individual network.On internal dataset it had accuracy of 96.74% and sensitivity of 97.91% and specificity of 96%.

COVID-19 and non-COVID-19 Classification Studies.

DenseNet121-FPN and COVID-19Net based on deep learning (DL) were presented by Shuo Wang et al. they collect data from 5327 patients, out of them the data of 4106 used for pre training of deep learning for lungs features, the remaining 1266 patients out of them 924 were COVID-19 affected and 342 were affected by other pneumonia.Their models were totally automated as they perform the automatic segmentation of the lungs while masking the non-lung area.DenseNet121-FPN was used for the segmentation of lungs.The cubic bounding segmented the lung area masks and crops the lung area and defines it as region of interest after the suppression of the non-lung area after that the data were impeded to COVID-19Net for the diagnostic and the progression analysis. The obtained diagnostic results were very similar with the results of experienced radiologist. The sensitivity of these model was 90.7% specificity of 91.1% and 90.1% accuracy.

A CNN based MODE or multi-objective differential evolution model was developed by Dilbag Singh et al. They consider CNN a powerful tool for the classification of images.They hypothesized that the hierarchical structure and systematic characteristics extraction from the images makes CNN a versatile tool for the classification. In the first instance they formulated the layers in the three dimensions including width, height, and depth.Only a limited number of neurons were connected with next layer. In end, the output was reduced in a single vector having probability score and was synchronized alongside the depth dimension.Their model attains accuracy of 90% having the same sensitivity and specificity.AD3D-MIL or attention-based deep 3D multiple instance learning was developed by Zhongyi Han et al. they uses 460 chest CT images out of them 230 from 79 COVID-19 affected patients 130 from non-pneumonic and 100 from common Pneumonia.This model was generating the semantically deep Three-Dimensional instances followed by the most probable infected region.The model first converts the raw disparate bag into multiple Three-Dimensional instances along the semantic description.After this, it combines this with deep Three-Dimensional instances into bag representation for utilizing the attention-based multiple instance learning pooling.In last, it converts the bag representation in final divination because of using a neural network to absorb the Bernoulli's distribution of bag.These three steps then assemble into deep Three-Dimensional neural network for back-to-back enhancement. Empirical studies showed the accuracy of this model was 97.9%, with sensitivity of 97.9%.

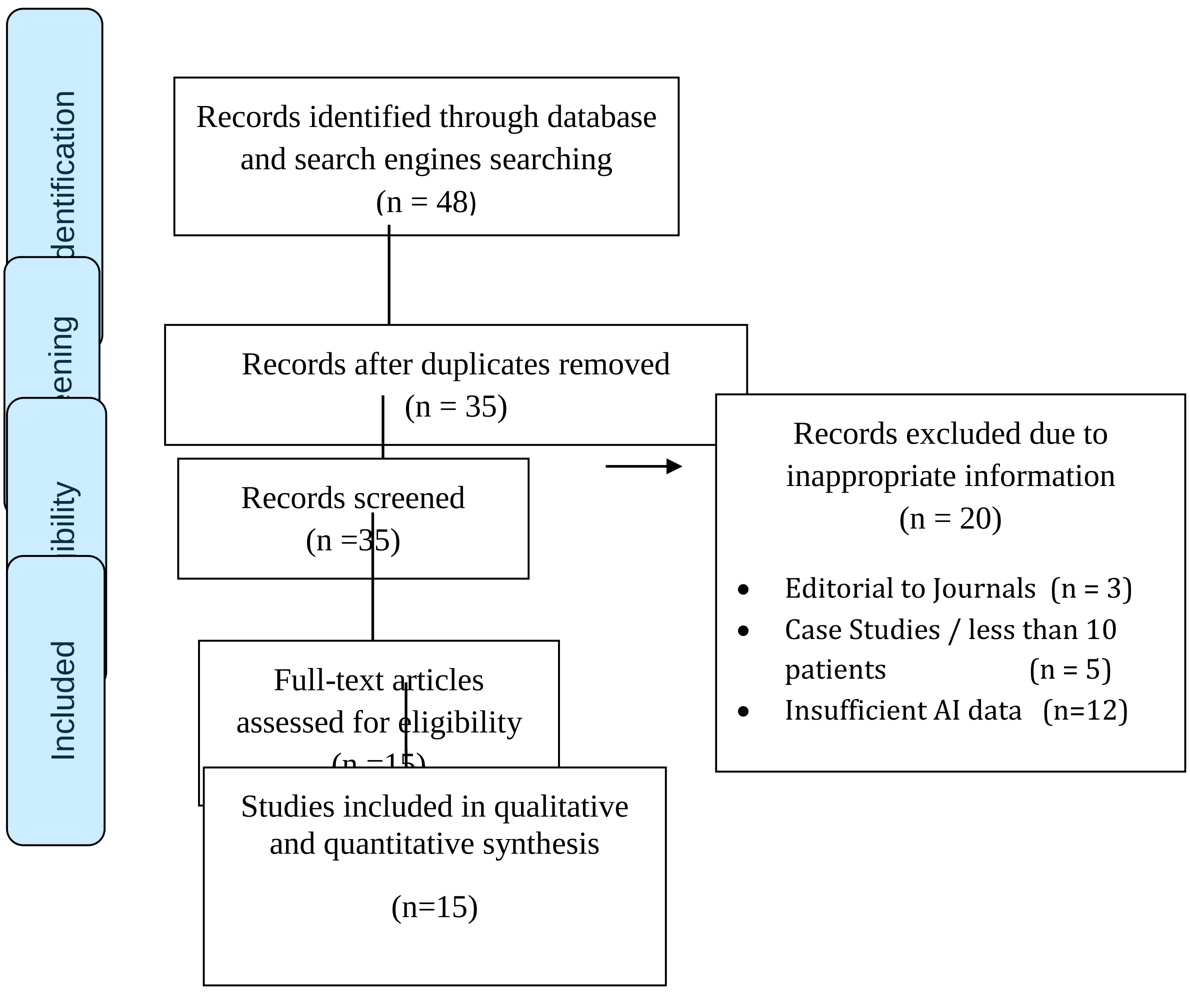
While working on AI Mohit Agarwal et al. presented nine kind of AI models for the classification of COVID-19 patients, namely they were; one DL based CNN, five TL based systems includes VGG16, DenseNet121, DenseNet169, DenseNet201 and MobileNet, three kind of ML based systems namely Artificial neural network (ANN), decision tree (DT), and random forest (RF).Their data was from 30 COVID-19 positive and 30 normal persons.They also used the three characterization systems comprised of Block imaging for COVID-19 severity index (CSI), Bispectrum analysis and block entropy.Their results showed that the DL have higher performance than ML.Using the k10 protocol, higher accuracy attained by DCNN and RF pairs which was 99.41% and 99.41% respectively, the ML and TL classifier attains lower accuracy percentage.

COVID-19/ Other Pneumonia Classification Studies:

Details Relation Extraction neural network or DRENet AI based model was given by Ying Song et al.The data was from 88 COVID-19 positive individuals, 100 bacterial pneumonia patients and 86 normal ones.For diagnostic purpose they detected the potential lesion regions by integrating the pre-trained ResNet50 with FPN network.The areas that were detected were again fed to ResNet50 for the extraction of local features at each region.Then these are sequenced with global features that were extracted from original images in order to transfer them to multiple layer perception for prediction at image level.For the assessment of efficacy they compared their model with ResNet, DenseNet and VGG16 but still their model maintain higher accuracy against them.The sensitivity and accuracy of this model was 96% and 86%.A multicenter based retrospective study was led by Lin Li et al. for the proposal of AI based model COVNet.This model was developed for the extraction of visual features of community acquired pneumonia and other pneumonia like abnormalities. For this purpose, they collected data from 3322 persons and then acquire the 4352 CT images, of them 1735 were community acquired pneumonic cases, 1292 from COVID-19 affected and 1325 from non-pneumonic.The framework of model used the RestNet50(16) as backbone.Model were using a sequence of chest CT slices as primary data and then generates features from them.After this these features were fed to max-pooling operation finally the terminal featured map fed to connected layers softmax activation function for the generating the probability score.The independent tested data set showed the specificity and sensitivity of this model as 96% and 90% respectively.Harrison X. Bai et al. developed EfficientNet B4. For the development of model, their data was from 521 COVID positive individuals and 665 non-COVID-19. The slices were piled up to three channels as the primary data of EfficientNet which was to utilize the pretrained on ImageNet. Independent tests were performed for the evaluation of performance of the model. They also compare their results with six experienced radiologists. Their model achieves the accuracy of 96% the sensitivity of 95% with the specificity of 96%.Hoon Ko et al. developed a Two-Dimensional DL skeleton namely the fast-track COVID-19 classification network or FCONet.They obtains data from 1194 COVID-19, 1357 other pneumonia, 998 normal, 444 lung cancer patients.This model has potential to diagnose COVID-19 on a single high resolution computed tomography (HRCT) of chest. Transfer learning while using VGG16, ResNet-50, Inception-v3 and Xception as mainstay but the FCONet based on ResNet-50 proves best model as it surpassed the other models in accuracy evolved this model.Transfer learning is renowned in computer vision as it allows the faultless models to construct in very limited time.The accuracy of this model was 99.87% and sensitivity of 99.58% with the specificity of 100%.

Segmentation, Characterization and lung tissue extraction studies:

Luca Saba et al. develop a powerful mechanism for the automatic extraction of tissue features and characterization of COVID-19 and non-COVID-19 pneumonia.They hypothesized that Artificial intelligence strategies provide quick detection and classification.They developed six models after acquisition from 100 COVID-19 positive and 30 non-COVID-19 persons, namely they were two traditional ML based k-NN and RF, two TL based VGG19 and InceptionV3 and two were custom-designed DL models namely CNN and ICNN.The accuracy of these models were 74.58%, 96.84%, 94.84%, 99.53%, 99.53%, and 99.69% respectively.A model trained on deep learning (DL) namely VB-Net for the segmentation of lungs was developed by Fei Shan et al. this model consists of two paths. For the training of model, they uses 249 images from 249 COVID-19 patients and data of 300 COVID-19 affected patients for the validation of their model.The first was a contracting path comprised of down-sampling and convolutional operations to withdraw the global image features.The second was expansive pathway which includes up-sampling and convolution operations to incorporate the fine-grained image features.On comparison with V-Net 14 the speed of VB-Net was satisfactorily fastened, the reason of it was its bottle neck structure that was incorporated in VB-Net.This model achieves the Sensitivity of 96.74%, specificity of 96% and accuracy of 96%.



1.1 PRISMA Flow diagram of literature searched

TABLE 1.2: Author name, publication year, number of patients, AI model used, sensitivity, specificity, accuracy and AUC of 15-screened studies.

Author	Year	Class	Number of patients	Model	Sensitivity %	Specificity %	Accuracy %	AUC %
Aayush Jaiswal et al	2020	COVID-19/ normal	1,262 COVID-19, 1,230 normal	DLT based DenseNet201	96.29	96.21	96.25	97
Runwen Hu et al	2020	COVID-19/ normal	521 COVID-19, 397 normal, 76 bacterial. pneumonia.48 SARS	Model based on ShuffleNet V2	90.52	91.58	91.21	96.89
Md Zahagir Alom et al	2020	COVID-19/ normal	178 pneumonia, 247 normal	IRRCNN,NABLA-N	N/A	N/A	98.78	N/A
Quan Zhang et al	2021	Diagnosis of COVID-19	61 COVID-19, 43 non-COVID-19	GARCD	96.97	91.16	NA	97.8
Kai gao et al	20	Diagnosis and evaluation of COVID-19	704 COVID-19, 498 normal	DCN	97.91	96	96. 74	97.55
Shuo Wang et al	2020	COVID-19/ non-COVID-19	5327 (4106 for pre training and 924 COVID-19, 342 other pneumonia)	DenseNet121-FPN, COVID- 19Net	90.7	91.1	90.1	95.9
Dilbag Singh et al	2020	COVID-19/ non-COVID-19	N/A	MODE	90	~90	~90	Not clear
Zhongyi Han et al	2020	COVID-19/ non-COVID-19	79 COVID-19, 130 non- pneumonia 100 common pneumonia	AD3D-MIL	97.9	N/A	97.9	99
Mohit Agarwal et al	2021	COVID-19/ non-COVID-19	30 COVID-19 , 30 non-COVID-19	DL based CNN, VGG16, DenseNet121,DenseNet169, DenseNet201, MobileNet, ANN, DT, RF	99, 80. 23, 93.8, 89.58, 91.57, 93.75, 91.48, 96.96, 99	98.57, 63.09,88.88,81.08,82.66,86.48,81.57,94.36,98.57	99.41, 71.86,91.56, 85.93,87.49, 90.93,87.31, 95.88,99.41	99, 71,91,85,87,89,86,94,98
Ying Song et al	2021	COVID-19/other pneumonia	88 COVID-19, 100 bacterial pneumonia, 86normal	DRENet	96	N/A	86	95
Lin Li et al	2020	COVID-19/other pneumonia	1292 COVID-19, 1735 CAP, 1325 normal	COVNet	90	96	NA	96
Harrison X. Bai	2020	COVID-19/ non-COVID-19	521 COVID-19, 665 non-COVID-19	EfficientNet B4	95	96	96	95
Hoon Ko et al	2020	COVID-19/ non-COVID-19	1194 COVID-19, 1357 other pneumonia, 998 normal, 444 lung cancer		99.58	100	99.87	100

				FCONet				
Luca Saba et al	2021	Characterization and extraction of tissue features	100 COVID-19, 30 non-COVID-19	K-NN,RF,VGG19,Inception V3,CNN,Icnn	50.97,90.65,86.24,98.99,98.99,98.99	90.99,99.26,98.13,99.64,99.64,99.64	74.58,96.84, 94.84,99.53, 99.53,99.69	74,94,96, 99,99,99
Fei Shan et al	2020	Segmentation and quantifiation of lung	549 COVID-19	DL-bsed VB-Net	96.74	96	96.74	98.64

SARS= Severe Acute Respiratory Syndrome DLT= Deep transfer learning model IRRCNN= Inception Recurrent Residual Neural Network GARCD= Generative Adversarial Residual Convolution Diagnosis MODE= Multi-objective differential evolution model AD3D-MIL= Attention-based deep 3D multiple instance learning **VGG16=** ANN= Artificial neural network DT= Decision tree RF= Random forest
CNN= Convolution Neural Network

Discussion

The 15 published articles are included in this study, which shows that the models based on AI plays key role in the diagnosis, differentiating, in extraction of features of COVID-19 pneumonia on Computed Tomography.After reviewing these articles, it is seen that Machine learning, Deep learning, Transfer learning and multiple instance learning remains the main the focus for the development or training of model in these studies. The deep learning in Convolutional Neural Networks were generally used in these studies for the automatic extraction of features from the Computed Tomographic generated images. CNN also uses for the enhancement of image quality, that can be compromised from patient motion and intubation etc. It is seen that some researchers also use the pretrained models and after performing alterations they use them in the tissue features extraction and COVID-19 classification. Especially the DenseNet121, ShuffleNet V2 and ResNet50 has been used by the researchers for the classification and UNet for the segmentation of lung to access the progress of virus.They also use the characterization systems, includes the Block Imaging for COVID Severity Index that uses Probability map computation block and color-coding block that is different for each probability score, Bispectrum analysis uses for the tissue characterization and Block entropy that gives values differ for healthy and diseased areas. Block Imaging shows satisfactory results for the infected patients. k-fold Cross validation was found a time taking process and do not have exemplary results, so research workers use hold-out method which was based on dataset division into training and testing set this improves their results with marked percentages.The preprocessed data improves the radiographic images in terms of allocating more systematic analysis and results. A few numbers of researchers also compare their results with trained radiologists and their results shows same results with them. The geographical information also interferes the efficiency of models, different variants with varying representation on CT images needs respective trained models for diagnosis.Besides a smaller number of patients availability, geographical data, they still unable to affects the performance of the models, results, and the potentiality of Artificial intelligence for the battle against COVID-19.

Conclusion

The virus is spreading continuously across the world, the use of AI in diagnosis of COVID-19 using CT as imaging tool in limited time is revolutionary.AI based models provide the rapid diagnosis of infection which results in the reduction of workload on radiologists and managing the patients. This also provides the images of improved quality that help in the early management of patients.The models based on AI can also provide the more accurate diagnosis in future.AI is also helping in the handling of many diseases.The data in these studies were from different institutes and scanners, because of this the results of respective studies can vary on other environment and some of the studies were based on limited number of individuals, by improving the demographic and clinical information AI based models can make rapid and accurate diagnosis in future and can proves a supportive method for radiologists in interpretation of their results.

Conflict of interest:None declared

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