Application of Artificial Intelligence in Human Diagnosis and Public Health Management

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Research Article

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Abstract

To improve the diagnostic efficiency and accuracy of corona virus disease 2019 (COVID-19), and to study the application of artificial intelligence (AI) in COVID-19 diagnosis and public health management, the computer tomography (CT) image data of 200 COVID-19 patients are collected, and the image is input into the AI auxiliary diagnosis software based on the deep learning model, "uAI the COVID-19 intelligent auxiliary analysis system", for focus detection. The software automatically carries on the pneumonia focus identification and the mark in batches, and automatically calculates the lesion volume. The result shows that the CT manifestations of the patients are mainly involved in multiple lobes, and in density, the most common shadow is the ground glass opacity. The detection rate of manual detection method is 95.30%, misdiagnosis rate is 0.20% and missed diagnosis rate is 4.50%; the detection rate of AI software focus detection method based on deep learning model is 99.76%, the misdiagnosis rate is 0.08%, and the missed diagnosis rate is 0.08%. Therefore, it can effectively identify COVID-19 focus and provide relevant data information of focus to provide objective data support for COVID-19 diagnosis and public health management.

1. Introduction

A type of 2019 novel coronavirus (2019-nCoV) induced pneumonia breaks out in Wuhan city, Hubei province, in December 2019, then spreads to all provinces and regions of China and several countries and regions, and the World Health Organization declares it as a public health emergency of global concern [1, 2]. Understanding and characterizing the virus in time to fight the epidemic is crucial. 2019-nCoV is more likely to grow in primary human airway epithelial cells and has a strong ability to infect people [3]. Corona virus disease 2019 (COVID-19) is mainly transmitted through respiratory droplets and contact transmission, is generally susceptible to the population, can cause fever, cough, fatigue or myalgia and other symptoms, and half of the patients can have dyspnea [4, 5]. Most of the patients are moderate and mild, the prognosis is good, and a few patients are critically ill and even die [6]. COVID-19 presence poses a serious threat to human health. At present, with the development of epidemic situation, researchers have a deeper understanding of the new type of coronavirus pneumonia, and the grasp of the epidemiological characteristics of the disease is also constantly changing and improving [7, 8]. Effective and timely diagnosis of COVID-19 and better public health management can save lives, reduce suffering and minimize impact.

CT examination is an important method for the diagnosis of COVID-19. CT examination, with its advantages of high accuracy, convenience, good repeatability and high positive rate, has played an important role in screening, disease change evaluation and public health management of patients with COVID-19 [9, 10]. Typical CT imaging features of COVID-19 are multiple ground glass opacity (GGO) with or without pulmonary consolidation on the periphery of both lungs, and early imaging examination is dominated by thin-layer high-resolution CT scanning [11]. Because the patient's condition changes quickly in the short term, after many re-examination CT, massive images greatly increase the diagnostic workload of imaging physicians. In recent years, AI algorithms have been developed rapidly with the application of big data and the continuous improvement of computer computing ability. AI technology can obtain all kinds of information easily ignored and/or can't be extracted by the naked eye from the image, thus improving the diagnostic efficiency of the image [12]. The use of AI technology to detect pulmonary nodules is the focus of the development of AI medical industry. Setio et al. (2016) proposed a lung nodule detection method based on convolutional neural network algorithm. 76.00% sensitivity and 0.25 false positive rate of CT per case were obtained in the test of dataset [13]. Different from traditional machine learning methods which need to extract artificial design features, deep learning can directly learn abstract and deep image features from raw image data [14]. Therefore, deep learning techniques have been used in large-scale computer-aided detection systems for chest CT pulmonary nodules [23].

To sum up, in order to improve the diagnostic efficiency and accuracy of COVID-19, combined with AI assisted diagnosis technique and artificial review, its application value in COVID-19 focus screening and disease assessment are analyzed in the experiment, so as to provide reference basis for COVID-19 diagnosis and public health management, which is of great significance.

2. Materials And Methods

2.1. Research object

Two-hundred patients: 106 males and 94 females, diagnosed as COVID-19 in Hubei Hospital (During January 2020 to April 2020) were collected. The experiment was reviewed and approved by the hospital ethics committee and all patients signed relevant informed consent.

Inclusion criteria: All patients met diagnostic criteria of the national health commission's *Pneumonia Diagnosis and Treatment Program for New Coronavirus Infection*; Clinical manifestations of fever, cough and fatigue, all patients with high resolution CT plain scan of chest, and clinic data perfect.

Exclusion criteria: Patients with poor chest CT image quality, impact assessment, or no second CT examination, patients with negative nucleic acid detection, patients with lung cancer, severe interstitial pneumonia, pulmonary edema, or other causes of severe pulmonary parenchymal lesion, and patients with incomplete clinical data.

2.2. CT scanning method

The CT examination of all patients was performed using a 64-row multi-layer spiral CT scanner (General Electric Company, USA). Two operation technicians were set up and carried out level 2 and above protection, one of them was responsible for patient placement, and the other one was responsible for scanning operation. As far as possible operation was compartment if conditions permitted. Patients and accompanying personnel wore masks, and each patient was checked with a one-time single to separate from the examination equipment. The patient was trained to breathe before the scan and held his breath at the end of the inhale. The patient performed a full lung scan with a breathless breath after inhalation, ranging from the tip of the lung to the angle of the ribbed diaphragm. The scanning parameters were as follows: tube voltage 120kV, tube current 225mA, layer thickness 1.5mm, image matrix 512mm×512mm, visual field 360mm×360mm. Reconstruction algorithm was a standard algorithm reconstruction for 1.25mm layer thickness axial image reconstruction. After scanning, the equipment, machine room and patient passage were disinfected by the hospital sterilization and antivirus team.

2.3. Methods of focus detection in AI software based on deep learning model

UAI, the COVID-19 intelligent auxiliary analysis system (uAI-Discover-NCP, Lianying Group), an AI assisted diagnostic software based on deep learning model, was used to detect focus. The original CT raw data of all COVID-19 patients were transmitted to the AI software workstation, the software system automatically identified and labeled pneumonia focus in batches, and presented the calculated data in the form of pictures and charts, including the total volume of lesion, the volume of internal GGO and the volume of real variable region. The automatically detected target focus were marked and numbered in boxes on various images, basic information such as focus area, volume, length diameter and CT value were provided, and the corresponding recognized and labeled nodules could be displayed on the sliding image layer at all levels. The local 3D reconstruction map could be rotated in multiple directions to show the anatomical structure of the target focus and its position relationship with the surrounding tissue. All imaging physicians had received relevant professional training and were familiar with the operation process and related matters of the software. Based on the images shown in the image archiving and communication system, the primary imaging physicians checked the focus identified by the AI assisted diagnostic software, and recorded the false positive or false negative situation in the software recognition area. Finally, the final review was carried out by two senior diagnostic physicians with rich experience in diagnosis, a few false positive or false negative images were repaired manually, and the final review results shall prevail. All patients underwent clinical treatment for 3 to 5 days before CT reexamination to assess the patient's disease progression.

2.4. Manual detection method

Image measurement and analysis were evaluated by two radiologists with more than 5 years of experience in diagnosis, and consensus could be reached through consultation with a senior radiologist with more than 10 years of experience when opinions differed. Mainly evaluate the pneumonia performance included GGO, consolidation shadows, mixed density GGO shadow, air bronchus sign, grid shadow, central lobules nodules, and pleural downline samples sign, cystic degeneration and bronchiectasis, GGO showed increased slight of pulmonary parenchymal density, and the bronchial vascular in the lesion area was still displayed. Consolidation shadows showed increased pulmonary parenchymal density, and the vascular shadow was not visible in the lesion area. The distribution of the focus was divided into peripheral and central, the peripheral distribution was the lateral 1/3 of the lung, and the central distribution was the medial 2/3 of the lung. Other abnormal pulmonary lesion, such as fibrous changes, nodules, calcification, masses, voids, lymph node lesion and pleural effusion, were also recorded. The cumulative number of lobes was recorded, and the involvement of a single lobe or multiple lobes was assessed and recorded.

2.5. Statistical methods

SPSS 26.0 statistical software was used for data analysis, the measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$), t test was used for the comparison of the two samples, the counting data was expressed as incidence n (%), x^2 test was used for the comparison, and all of them were statistically significant with $P < 0.05$.

3. Results

3.1. Basic information on patients

Among the 200 confirmed COVID-19 patients, 147 were normal patients, 40 were severe patients and 13 were critical patients. The basic situation of the patients was shown in Table 1, and among the 200 confirmed COVID-19 patients, 106 were males and 94 were females, aged from 28 to 75 years old, with an average age of (50.34 ± 12.65) years old. The patient's body temperature at admission was 36.7 ~ 38.5℃. The main clinical manifestations of the patients were shown in Table 2, including 20 cases of expectoration (10.00%), 113 cases of fever (56.50%), 33 cases of chest tightness (16.50%), 140 cases of cough (70.00%), 13 cases of headache (6.50%), 20 cases of pharyngeal pain (10.00%), 27 cases of chills (13.50%), and 7 case of digestive system symptoms (3.50%).

Table 1
The basic information on patients

Basic information	Value
Gender male [case (%)]	106 (53.00)
Age (years)	50.34 ± 12.65
Body temperature (℃)	37.5 ± 0.8
Heart rate (beat/min)	102 ± 9
Frequency of breath (time/min)	19.3 ± 1.0
Systolic pressure (mm Hg)	150 ± 6
Diastolic pressure (mm Hg)	94 ± 4
Blood oxygen saturation	97.2 ± 0.5

Table 2
Main clinical manifestation of patients

Clinical manifestation	Cases	Proportion
Expectoration	20	10.00%
Fever	113	56.50%
Chest tightness	33	16.50%
Cough	140	70.00%
Headache	13	6.50%
Pharyngeal pain	20	10.00%
Chills	27	13.50%
Digestive system symptoms	7	3.50%

3.2 CT manisfestations of patients

The CT characterization results of the patient were shown in Fig. 1. Among the 200 patients diagnosed with COVID-19, CT manifestations were mainly multiple lobes involvement, including 127 cases (63.50%) of the left upper lobe, 180 cases (90.00%) of the left lower lobe, 113 cases (56.50%) of the right upper lobe, 100 cases (50.00%) of the right middle lobe, and 173 cases (86.50%) of the right lower lobe. In terms of density, 187 patients (93.50%) developed GGO, 167 patients (83.50%) had focal mesophilia, 153 patients (76.50%) had air bronchus sign, 100 patients (50.00%) had consolidation shadows, and 53 patients (26.50%) had central lobular nodules. No lymphadenopathy and pleural effusion were observed in all patients CT examination.

Typical CT images of patients were shown in Fig. 2. Clinical common type patients CT showed unilateral or double lung multiple focus, a slice or wedge shaped GGO, the vessels and bronchi could be seen inside, often accompanied by thickening of interlobular septum, "paving stones" sign and bronchial inflatable sign, and lung consolidation could be seen inside some lesions. In the typical clinical common case shown in Fig. 2a, CT scan of a patient with COVID-19 showed GGO in the peripheral zone of both lower lungs, with a grid shadow seen inside. The CT of clinically severe and critically ill patients showed a wide range of lesion, GGO, solid-shadow and fiber-strip shadow, with "paving stone" sign, bronchial inflatable sign. In Fig. 2b, a CT cross-sectional scan of a patient with COVID-19 in the typical clinical severe case showed the air bronchi sign in the periphery zone GGO of the lower lobe of the right lung.

3.3. The evaluation results of patient's condition by AI software focus detection method based on deep learning model

The evaluation results of patient's condition by AI software focus detection method based on deep learning model was shown in Fig. 3. The AI assisted diagnostic software could automatically identify and label the pneumonia focus. The total volume of the patient's focus, the shadow volume of internal GGO and the volume of solid areas were automatically calculated by the software. After 3–5 days of clinical treatment, CT re-examination showed that, among the 200 patients, the total volume of focus, the volume of internal GGO and the volume of real variable region of 21 patients decreased accordingly. In 6 patients, the total volume of leisions, the volume of internal GGO or the volume of real variable region increased accordingly; while in 3 patients, the total volume of leisions, the volume of internal GGO or the volume of real variable region did not change significantly.

3.4 Comparison of two methods for detection of focus

The comparison results of focus marker range between the two methods were shown in Fig. 4. It could be seen that the focus marker range of the deep learning model-based AI software focus detection method (Fig. 4a) was more consistent than that of the manual detection method (Fig. 4b).

There were 2533 focus in 200 patients. The detection of lesion in the two methods was shown in Table 3, in which 2527 focus were detected by AI software based on deep learning model, 5 lesions were missed and no errors were detected. A total of 2533 focus were detected by manual detection, among which 5 lesions were miss-detected and 114 lesions were missed. Among them, the detection rate of focus in COVID-19 patients by AI software lesion detection method based on deep learning model was 99.76%, the error detection rate was 0.08%, and the missed diagnosis rate was 0.16%. The detection rate of the lesions by manual detection method was 95.30%, the error detection rate was 0.20%, and the missed diagnosis rate was 4.50%. It could be seen from this that the detection rate of AI software focus detection method based on deep learning model was significantly higher than that of manual detection method, while the rate of misdiagnosis and missed diagnosis was significantly higher than that of manual detection method, and the difference was statistically significant ($P < 0.05$).

Table 3
Detection of lesions by two methods of focus detection

	AI software based on deep learning model	Manual detection	P
Focus detected	2527	2414	
Detection rate	99.76%	95.30%	0.035
Missed focus	4	114	
Missed diagnosis rate	0.16%	4.50%	0.022
Misdetection of focus	2	5	
Misdetection rate	0.08%	0.20%	0.113
Note: P<0.05 indicates statistical significance.			

4. Discussion

According to *Pneumonia Diagnosis and Treatment Program for New Coronavirus Infection (trial fifth edition)*, "suspected cases with pneumonia imaging characteristics "has been included in the Hubei Province clinical diagnostic criteria, and CT imaging is one of the important bases for diagnosis and evaluation [15]. However, due to the large number of patients, multiple focus in lung, rapid change progression, and the need for multiple re-examination in a short period of time, the accurate diagnosis and quantitative analysis of imaging doctors are facing great challenges. In recent years, the excellent performance of AI assisted diagnosis technology in medical field has received great attention, especially in the screening and diagnosis of pulmonary nodules, which is more sensitive than imaging physicians. AI as an auxiliary diagnostic technique can help imaging physicians improve their work efficiency and diagnostic accuracy [16–18]. CT image data of 200 patients with COVID-19 were collected in experiment, and the images were input into the AI assisted diagnostic software based on deep learning model for focus detection. The results showed that clinical common type patients CT showed unilateral or double lung multiple focus, a slice or wedge shaped GGO, the vessels and bronchi could be seen inside, often accompanied by thickening of interlobular septum, "paving stones" sign and bronchial inflatable sign, and lung consolidation could be seen inside some lesions. The CT of clinically severe and critically ill patients showed a wide range of lesion, GGO, solid-shadow and fiber-strip shadow, with "paving stone" sign, bronchial inflatable sign. After 3–5 days of clinical treatment, CT re-examination showed that, among the 200 patients, the total volume of focus, the volume of internal GGO and the volume of real variable region of 21 patients were decreased accordingly, indicating that the patients' condition had a certain degree of improvement. In 6 patients, the total volume of focus, the volume of internal GGO or the volume of real variable region were increased, indicating that the patients' condition had a certain degree of deterioration. In 3 cases, the total volume of focus, the volume of internal GGO or the volume of real variable region did not change significantly, and the change of the disease was not obvious. It can be seen that the deep learning model-based AI software focus detection method can be applied in the diagnosis of COVID-19 and can effectively evaluate the patient's condition.

Deep learning techniques can effectively accomplish the tasks of image detection, recognition and classification, so the introduction of deep learning techniques in the field of imaging may help radiologists to complete various tasks of detection and diagnosis [19, 20]. Pulmonary nodule detection using AI algorithm is an important part of AI medical field [21]. Results show that the range of focus markers of the two detection methods is consistent, but the detection rate of AI software focus detection method based on deep learning model is significantly lower than that of manual detection method ($P < 0.05$), while the misdiagnosis rate and missed diagnosis rate are significantly higher than that of manual detection method ($P < 0.05$). It can be seen that the detection ability of AI software focus detection method based on deep learning model is not as good as that of manual detection method at present. This may be related to the current insufficient number of uAI-Discover-NCP learning cases at present, the deep learning algorithm needs to make a trade-off between sensitivity and specificity of the focus detection, which is still in the exploratory testing phase. In addition, the detection of focus has a certain relationship with their size and nature. Computer deep learning and depth algorithms can be extended with the expansion of data, with the improvement of AI assisted diagnostic performance, it is expected to improve the accuracy of focus detection, reduce the number of daily tasks that take time and effort, and liberate part of the workload of imaging doctors. Brown (2020) studies have shown that the progression of chest CT in patients during hospitalization is able to predict patients' response to treatment and help distinguish between critical and non-critical patients [22]. Results of this experiment also suggest that chest CT can reflect the value of changes in pneumonia, but whether these changes affect the prognosis of patient needs further analysis

To sum up, the false detection rate and missed diagnosis rate of AI assisted diagnostic software based on deep learning model are higher than that of imaging physician's manual detection method, and the detection ability still needs to be improved. Overall, however, AI assisted diagnostic CT has a good ability to detect lesion in COVID-19 patients, and can effectively identify the focus, provide relevant data information such as the total volume of the focus, the internal GGO and the volume of solid change, and show the variation of lesion range and internal density, which not only provide objective imaging support for COVID-19 diagnosis and public health management, but also improve the efficiency of imaging physicians.

5. Conclusions

COVID-19 patients are studied to explore the application of AI in the diagnosis of new type of coronary pneumonia and public health management. The results show that the AI assisted diagnosis CT can effectively identify COVID-19 focus, provide information about the total volume of lesion, the internal GGO and the volume of real variable region, and show the variation of lesion range and internal density. For the diagnosis of COVID-19 and the management of public health, the reference basis is provided by the experiment, which has important theoretical significance and application value. There are still some shortcomings in the research process, due to the constraints of conditions, the sample data collection is less, resulting in a certain degree of deviation in the results. Therefore, the data capacity will be further increased in the later research process, so that the results obtained are more valuable for reference.

Declarations

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Figures

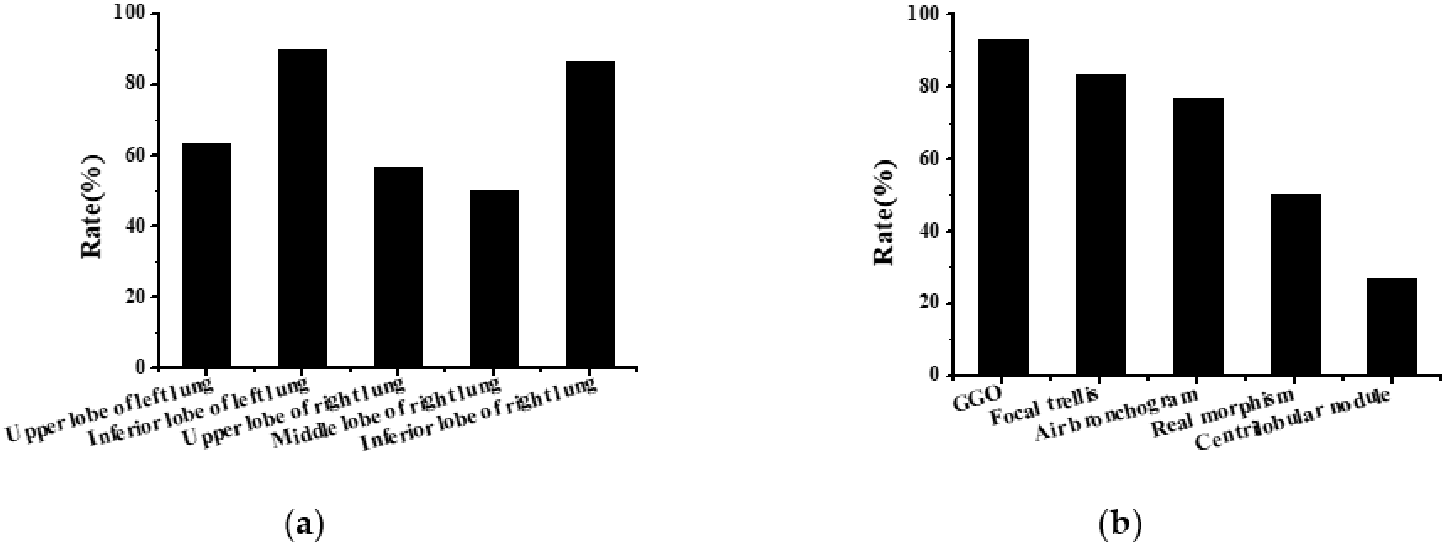

Figure 1

Patients' CT characterization results: (a) pulmonary lobe involvement; (b) proportion of CT signs.

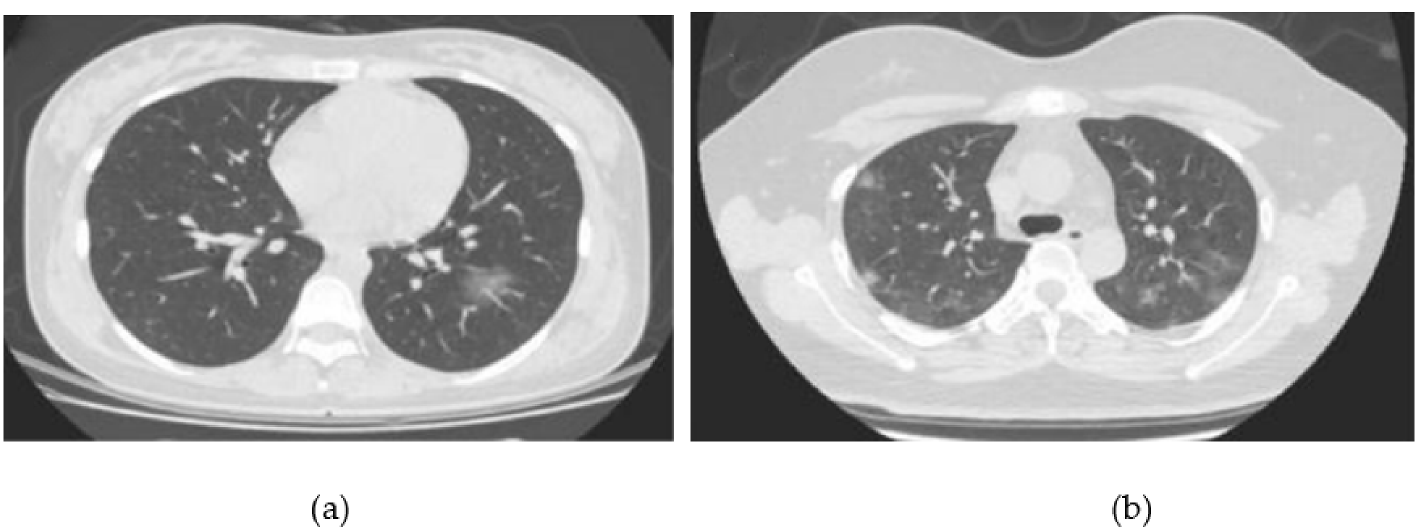

Figure 2

Typical CT images of patients: (a) clinical common patients; (b) the main manifestations of GGO shadows in patients

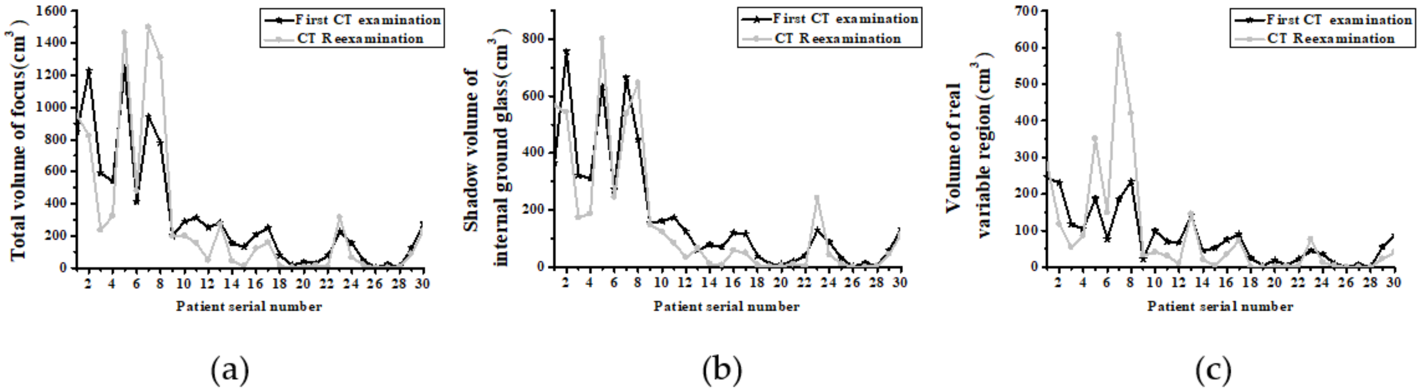

Figure 3

The evaluation results of patient's condition by AI software focus detection method based on deep learning model: (a) Total volume of the focus; (b) Internal GGO volume; (c) the volume of the real variable region.

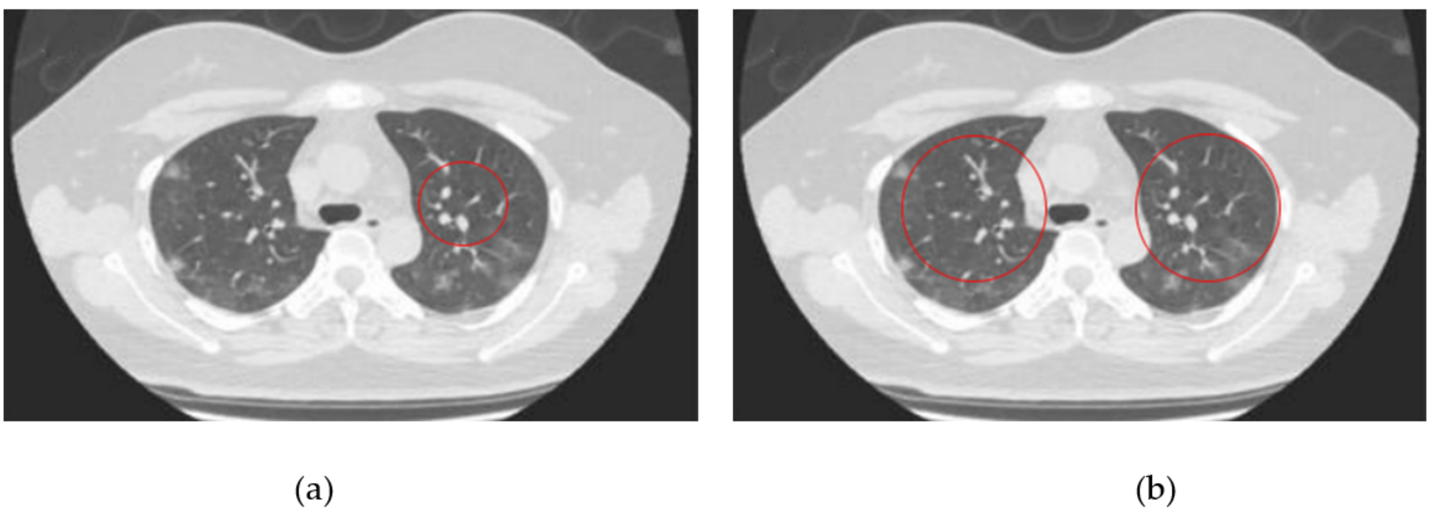

Figure 4

The comparison of focus marker ranges between the two methods of focus detection: (a) AI software lesion detection method based on deep learning model; (b) Manual testing methods