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Research Article

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# Artificial Intelligence with based Chest X-ray Image Analysis Screening 2019 Novel Coronavirus Pneumonia (COVID-19)

**Prapasri Benchasiriluck, Ph.D.[1], Prof.Wasun Chantratita, Ph.D.[2], Assoc.Prof.Sathit Niramitmahapanya, M.D.[3], Tarit Taerakul, M.D., M.S[4], Assist.Prof.Krisna Dissaneevate, M.D.[4], Thouantosaporn Suwanjutah, M.D.[5], Ronasit Poomma[6], Arakin Rakchittapoke[7], Sonchai Seangtian[7] and Peerapong Modethes[1*]**

[1]*Center of Private Research and Innovation Accelerator, Thailand*

[2]*Center for Medical Genomics, Mission Support Center, Mahidol University Faculty of Medicine, Ramathibodi Hospital, Thailand*

[3]*Department of Medical Innovation, Rajavithi Hospital, Thailand*

[4]*Department of Radiology, Rajavithi Hospital, Thailand*

[5]*Phyathai 2 Hospital, Bangkok, Thailand*

[6]*Mellow Innovation Company Limited, Thailand*

[7]*Advanced Info Service Public Company Limited, Thailand*

***Correspondence to:**
Peerapong Modethes
Center of Private Research and Innovation Accelerator, Thailand.
**E-mail:** peerapong_mod@phyathai.com

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## Abstract

The objectives of this experimental research were to study the usage of artificial intelligence (AI) in chest X-ray (CXR) analysis of pneumonia, which has been proven to be significantly accurate and effective in rapid screening for coronavirus disease 2019 (SARS-CoV-2). The study revealed no difference in results when comparing CXR analysis between AI and radiologists. Furthermore, AI intelligence is also compatible with complex diagnosis, such as the fifteen types of lung diseases. Samples were calculated using W.G. Cochran's formula, while data collection was done using probabilistic sampling techniques, which produce a 95% confidence interval for an unknown population. At first, 10,000 samples were collected, resulting in a 1% error. To minimize the potential error, 12,881 samples were collected instead and divided into three phases: 210 cases, 1,100 cases, and 11,571 cases, respectively. According to results, the prognosis of pneumonia's classification models was revealed by a dataset of AUC and ROC scores (area under the receptor functional curve: AUC). Model 1 and Model 2 show different types of histogram distribution values, which are 0.97 and 0.96, respectively. And the combined model got 0.98 AUC scores, which seem to have a better performance than each model in action by having a value of 0.98 AUC. During Phase 1, some significant values were revealed: high-performance AUC of 0.9878, sensitivity of 0.9717, and specificity of 0.9198. In Phase 2, data were obtained from comparative tests between AI and radiologists, which are 94% accurate. In Phase 3, data were collected from 11,571 samples. CXR images were analyzed by AI. 1,628 images were shown as positive for pneumonia detection (14%), and 9,943 images were shown as negative (86%). In addition, by using real-time RT-PCR examination, 19 samples were detected with Coronavirus disease 2019 infection (0.16%), and 11,552 samples were undetected (99.84%). Throughout the 3 phases of this research, pneumonia and pulmonary tuberculosis were found, and their severity was accelerating. There were 10 positive samples from nasopharyngeal swab tests for Coronavirus disease 2019 infection, while others (9 in number) were inconsistent; this could possibly be related to new variants of Coronavirus disease 2019 that are currently spreading. Therefore, it's necessary to make sure this study could go further to provide an effective and accurate result that would allow patients to receive proper treatment in time.

## Keywords

Artificial intelligence, Chest X-ray, Pneumonia, Coronavirus disease 2019

## Introduction

An epidemic situation of the novel coronavirus disease of 2019 was first reported in Wuhan, China. There has been a sequential increase in the number of unknown pneumonia cases in Wuhan since December 31st, 2019. Later, it was officially reported on January 3rd, 2020, that the known virus responsible for this epidemic situation is the novel coronavirus 2019 (2019-nCoV). Moreover, an acceleration in the number of patients outside China, such as in South Korea, Italy, Iran, Spain, France, the United States, and so on, is rapidly rising. Approximately 3,000 - 4,000 new cases and 200 - 300 deaths per day (3.5%) were found. Most of the patients with severe symptoms were the elderly, smokers, and people with underlying medical conditions such as heart disease and diabetes.

This new disease was initially predicted to be an infection from animals to humans, and its outbreak was closely monitored around the world (World Health Organization, 11th March 2020). Its severity remains unpredictable. Most of the patients who got infected with this coronavirus disease are showing signs of fever, cough, sore throat, and difficulty breathing. Some may develop severe pneumonia, in which fatality rates are high. Coronavirus can be transmitted from person to person by large droplets produced during coughing and sneezing (droplet transmission). An incubation period of the coronavirus in a patient is approximately 2 - 14 days or more, and there are reports showing recurrence in patients who have recently been treated.

Recently, the number of newly infected cases in both Thailand and worldwide is still accelerating, and it's difficult to measure the exact number of infected people due to the coronavirus's global outbreak. There is no telling when this hazardous epidemic is going to end [1-15].

The research team therefore presents a newly developed project that extends parts of existing knowledge in medical innovations and other known resources. Our aim is to combine an AI technology, which has been FDA (Food and Drug Administration)-approved from South Korea, with CXR image analysis of pneumonia for an effective coronavirus disease screening in 2019. Regarding Thailand's FDA certificate, there has been a cooperative effort between South Korea and Thailand's research team to obtain its verification. To improve AI's precision in rapid screening and diagnosis for those who have a risk of coronavirus disease infection in 2019. And by setting low production costs, it will be a great help to general hospitals and others that need effective tools to detect the SARS-CoV-2 genotype, which is located differently in the suburbs of Thailand. To reduce the risk of virus spreading from a group with Coronavirus disease 2019 infection and to prevent risky situations that will lead to Phase 3 of severe disease outbreaks.

Medical specialists will take part as counselors in this research project, while an AI system will be compared with radiologist skills to perform a comparative test and analyze results from CXR images. As a result, users can rest assured by acknowledging the total diagnostic performance of this AI system [16-20].

## Objectives

1. AI in the screening and analysis of CXR images of pneumonia can be applied to rapid screening for Coronavirus disease 2019 with 90% efficiency and accuracy.
2. The comparative test that analyzed and diagnosed CXR images between AI and a radiologist showed no difference.
3. The performance of the CXR portable kit and AI with based CXR image analysis in screening for the risk group of pneumonia infected with the Coronavirus disease in 2019 patients revealed statistically significant results.
4. AI based on CXR image analysis can diagnose pneumonia from other causes of lung diseases.

## Research hypothesis

While screening for pneumonia caused by the coronavirus disease of 2019, AI with CXR image analysis had 90% efficiency when compared with radiologists. The results of the comparative test between AI and radiologists revealed no difference. The performance of the CXR portable kit and AI with based CXR image analysis in screening for the risk group of pneumonia infected with the Coronavirus disease in 2019 patients has been statistically significant.

## Materials and Methods

### Research model

This study is experimental and has been reviewed and approved by the Human Research Ethics Committee of the Phyathai and Paolo Hospital Group.

### Populations and samples

The population in this study were divided into 2 groups: PUI and non-PUI.

### Patients under investigation: PUI (volunteers)

Considered from symptoms and symptoms together with risk factors are as follows:

**Situation 1:** Surveillance at the International Communicable Disease Control checkpoint discovered a patient with symptoms as follows: elevation of body temperature (37.5 degrees Celsius or more), respiratory symptoms such as cough, runny nose, sore throat, shortness of breath, or difficulty breathing.

**Situation 2:** Surveillance at hospitals discovered a patient with symptoms as follows: An elevation of body temperature equals 37.5 degrees Celsius or more with the display of respiratory symptoms such as cough, runny nose, sore throat, shortness of breath, or difficulty breathing. Pneumonia patients with unknown causes.

Both situations above have histories of 14 days before symptoms are displayed as follows: Had a history of traveling to or from or living in an area where the coronavirus disease

19 outbreak has been reported. A person who has close contact with tourists from an area where the continuation of the coronavirus disease outbreak has been reported. Having a close history with or having close contact with a patient who is either suspected or confirmed to have a coronavirus disease infection.

**Situation 3**: Surveillance at hospitals has discovered a suspected or confirmed patient with pneumonia or pneumonia with unknown causes.

**Situation 4:** A patient who died from severe pneumonia with unknown causes or probable patients who meet the criteria for disease investigation with a laboratory test have been discovered with a trace of Coronavirus 19's genotype and confirmed by using the PCR method from another laboratory.

## Non-patients under investigation: Non-PUI (volunteers)

Samples are divided into 3 different groups for each phase.

**Phase 1:** The sample group consists of 210 CXR images, selected by a specific sample of the population; 127 patients with COVID-19 infection: 15 patients from Phyathai 1 Hospital, 43 patients from Phyathai 2 Hospital, 28 patients from Paolo Phaholyothin Hospital, and 41 patients from Rajavithi Hospital.

The collected data are from the patient's history from January 2019 - April 2020.

**Phase 2:** 1,100 CXR images and 1,100 specific samples of the population were selected from a patient who was diagnosed with pneumonia.

The collected data are from current patients. The G*Power Version 3.1 program is being used to calculate the samples of 1,051 patients. But in this study, the number of samples was limited, so only 1,100 were used.

**Phase 3:** 10,000 volunteered samples were selected from Phyathai 1 and 2 hospitals, Paolo Phaholyothin Hospital (a private hospital), Rajavithi Hospital (the Department of Medicine), Ananda Mahidol Hospital (the Royal Thai Army Medical Department), the Thailand Center of Excellence in Life Sciences (TCELS), Mellow Innovation Company Limited, Advance Info Service Limited, the Center for Medical Genomics at the Mission Support Center, the Mahidol University Faculty of Medicine at Ramathibodi Hospital, and other agencies.

Samples were calculated using W.G. Cochran's formula, while data collection was done using probabilistic sampling techniques, which comprised a 95% confidence interval for an unknown population and resulted in a 1% error.

## Sampling method

Our research team uses the random sampling technique, in which each unit of a population can be randomly drawn into a sample, mainly for the convenience of the research team.

Each unit of population is drawn from the sample group of those who cooperate in providing information and from users of AI. The total number of samples was supposed to be 10,000 but 12,798 were collected instead to reduce statistical error.

## Research's site

Phyathai 1 Hospital, Phyathai 2 Hospital, Paolo Phaholyothin Hospital (Private Hospital), Rajavithi Hospital (Department of Medicine), Ananda Mahidol Hospital (Royal Thai Army Medical Department), Thailand Center of Excellence in Life Sciences: TCELS (Public Organization), Mellow Innovation Company Limited, Advance Info Service Limited (Public Company), Center for Medical Genomics- Mission Support Center, Mahidol University Faculty of Medicine-Ramathibodi Hospital, and other agencies.

## Process of the study

### Phase 1

210 CXR images of COVID-19 patients were collected from Phyathai 1 Hospital, Phyathai 2 Hospital, Paolo Phaholyothin Hospital, and Rajavithi Hospital. They're taken in the Digital Imaging and Communications in Medicine (DICOM) formation, a standard guideline approved by the National Electrical Manufacturers Association (NEMA).

None of the diseases analyses had been identified on these images, which also included specific information such as first name, last name, patient identification number (HN), ID card number, or any identifiable information that belonged to their owner. To comply with the guidelines for compliance, Section 7th of the National Health Act 2007 related to medical prac-

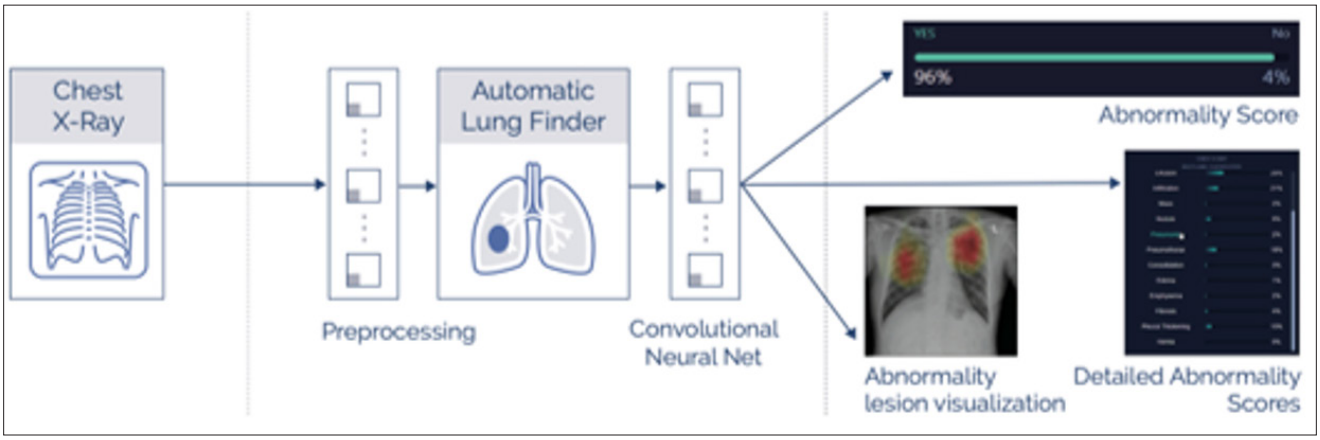



**Figure 1:** Showing CXR analysis, processing by AI.

titioners, staff who work at nursing homes, and public health care facilities. Updated: June 9th, 2017.

Each of the 210 CXR images will be analyzed by AI for screening and assessing the risk of any potential conditions or diseases (Figure 1).

## Phase 2

2.1. In the process of connecting the PACS (Picture Archiving and Communication System; PACS, managed by JF Advance Med company) system with Phyathai-Paolo Hospital's server, images taken from the CXR machine (Portable CXR) were stored. The PACS system will forward those images through a gateway connection for data collection. Next, radiologists or doctors (the research team) will retrieve data files and deliver them to AI's server. Then, it'll automatically analyze those files and display the results back on the computer screen (1,100 images total) through the gateway connection. These data files will be stored within PACS, which doctors are allowed to access through their own computers (Figure 2).

2.2. CXR images taken by a portable CXR machine will be stored and selected from Phyathai 1 Hospital, Phyathai 2 Hospital, Paolo Phaholyothin Hospital, and Rajavithi Hospital's samples by choosing only people that had been diagnosed with pneumonia. Data files will be forwarded to their PACS system. Next, the PACS system will deliver data files (images) through a gateway connection. Then, the research team will retrieve them and forward them to the AI with CXR server for analyzing the diagnostic results.

## Phase 3

3.1. Taking CXR images from a group of samples who live in a cluster environment to process with another CXR examination by conversing them into DICOM form. This standard guideline was set by the NEMA.

3.2 Preparation for X-ray Generator (Camera Type) and X-Ray Panel Detector with AI's Software Installation at PMC Group Hospitals.

3.3 Preparation for X-ray Generator (Camera Type) and X-Ray Panel Detector with AI's Software Installation at the Rajavithi Hospital.

3.4. Preparation for X-ray Generator (Camera Type) and X-Ray Panel Detector with AI's Software Installation at Another Volunteered Agency.

CXR images, which were obtained from the portable CXR machine, will be brought in for processing with an AI system. Results will automatically display on the user's computer screen at PMC Group Hospital and Rajavithi Hospital. Data were collected from 11,571 samples (Figure 3).

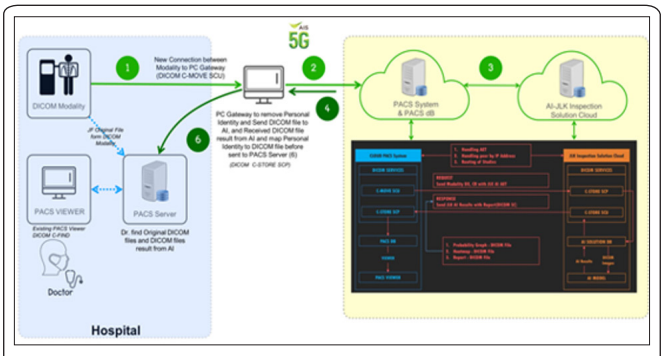



**Figure 2:** Showing AI's function.

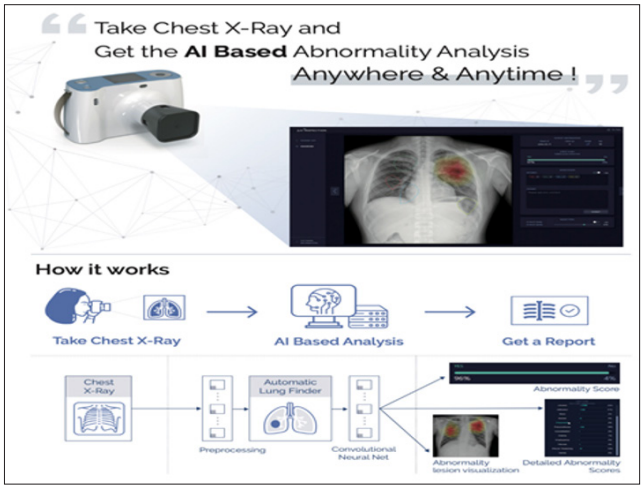



**Figure 3:** CXR images that were taken from a portable CXR machine.

3.5 In this process, 10,000 samples will be screened for pneumonia and discovered in Phase 3 CXR images by using AI. Next, we will deliver that specific patient to receive a CXR examination at the Radiology Department and proceed with a nasopharyngeal swab procedure later at Rajavithi Hospital. Then, send out 100 samples for detecting SARS-CoV-2 infection and get screening by Molecular Biology's technique, real-time RT-PCR, at the Center for Medical Genomics, Mission Support Center, Mahidol University Faculty of Medicine, Ramathibodi Hospital.

3.6 Center for Medical Genomics, Mission Support Center, Mahidol University Faculty of Medicine, Ramathibodi Hospital, continues processing with a nasopharyngeal swab procedure and pneumonia scanning (phase 3). Abnormal CXR images were detected.

A nasopharyngeal swab of 100 samples, who are at risk for Coronavirus disease 2019 infection, will be soaked in Viral Transport Medium for extracting the SARS-CoV-2 genotype. And they will be screened by Molecular Biology's technique, real-time RT-PCR, to compare the positive (detectable) and negative (undetectable) results with another group of results obtained from AI technology. It's verified as evidence from screening and analyzing 100 CXR images of a population who have a risk of being exposed to the COVID-19 virus and have displayed pneumonia symptoms in the same person (Figure 4).

## Statistics used in data analysis

Descriptive Analysis: for calculating basic statistic information such as frequency distribution, percentage, mean, and standard deviation (SD) by using table formation accompanied by descriptive interpretations to state details in various fields.

Comparative data analysis: an AI combined with CXR screening (for pneumonia caused by the 2019 coronavirus) can screen for pneumonia with 90% efficiency when compared with radiologist's detection. The results of these diagnostic tests can

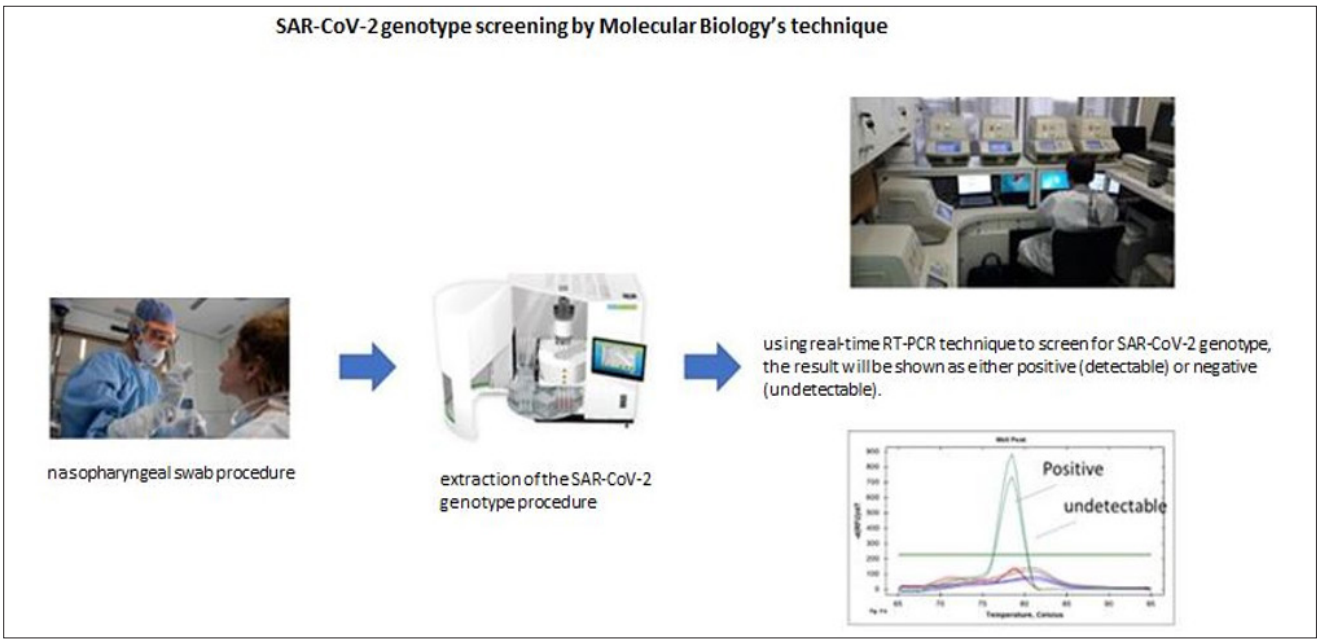



**Figure 4:** SARS-CoV-2 genotype screening by molecular biology's technique: Real-time RT-PCR.

be used to calculate sensitivity, specificity, accuracy, predictive values, and likelihood ratios (gold standard). Comparative data analysis is a standard for accurate measurement of the value obtained from the gold standard examination. It's proved to be an effective method in medical research. According to the comparative tests for CXR analysis, there was no difference in results between the AI and the radiologist. Data were analyzed using the T-test statistical method. By using Pearson's Correlation Coefficient for the statistic correlation test, data were processed by an instant computer program named SPSS Version 20 and AMOS 16. Results of comparative screening for a risk of pneumonia infected with Coronavirus disease in 2019 between a portable CXR machine and AI (based on CXR images) also revealed statistically significant results (Table 1).

AI is a computer system capable of performing tasks that require an input of data consisting of human intelligence such as visual perception. More than millions of CXR images have been added to the database to enhance its capabilities, such as the ability to make decisions and initiate data processing without any requirement of a command's code. AI is made up of two components: machine learning and convolutional neural networks, which in radiology are known as an advanced component of the deep learning process. In the field of specialized medicine, AI provides outstanding help in screening and analyzing for pneumonia by interpreting CXR results. To maximize the speed of the patient's transfer process and make it possible to begin a proper treatment in time. AI software used in this research was imported from South Korea by Mellow Innovation Co., Ltd. and JLK Inspection Korea PCL Co., Ltd., participating as part of an initial screening for infectious pneumonia caused by the 2019 Coronavirus disease in Thailand.

**Table 1:** Comparative data analysis.

| | | Radiologist gold standard | |
|---|---|---|---|
| | | **Positive** | **Negative** |
| AI diagnostic test | Positive | a (True Positive) | b (False Positive) |
| | Negative | b (False Negative) | d (True Negative) |

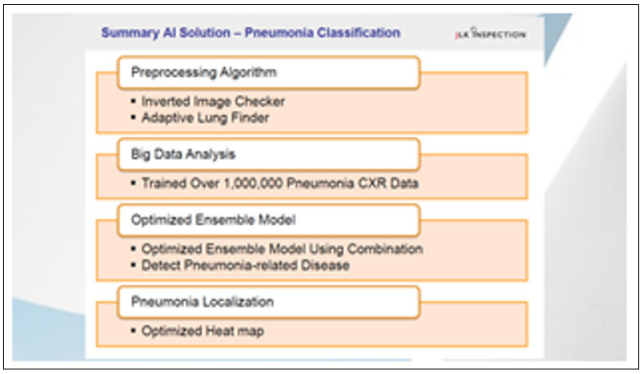



**Figure 5:** Summary AI solution-pneumonia classification.




**Figure 6:** Display results: Original image vs. heat map image.

The results of the study have been summarized as follows: Figures 5 to figure 9 display the results of "AI-based CXR Image Analysis for 2019 Novel Coronavirus Case Study" by JLK INSPECTION, Inc.

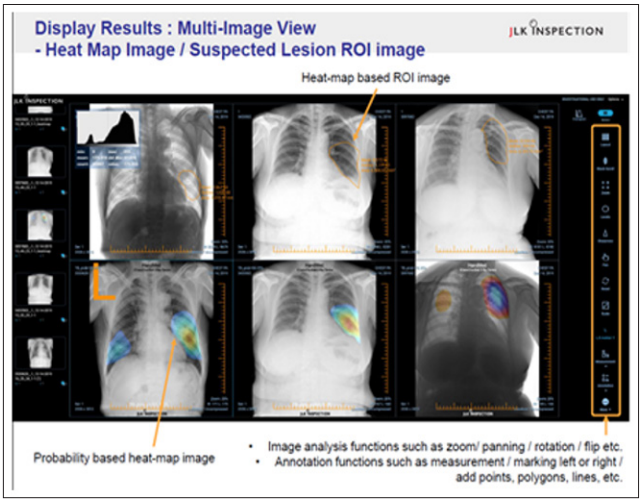



**Figure 7:** Display results: multi-image view-heat map image/suspected lesion ROI image.

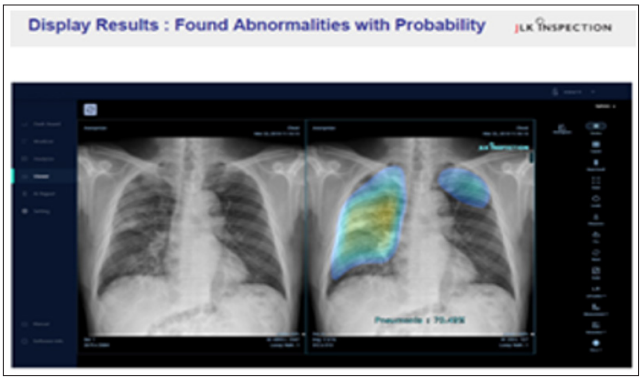



**Figure 8:** Display results: Found abnormalities with probability.

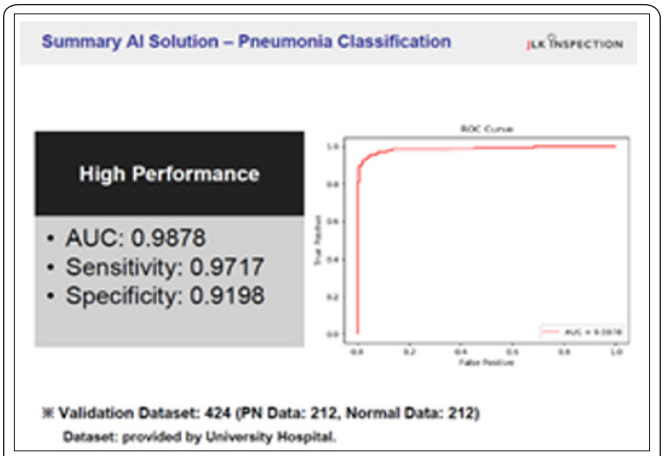



**Figure 9:** Prognostic results of pneumonia classification model (AUC and ROC dataset).

## Results

Prognostic results of the pneumonia classification model by AUC and ROC dataset (area under the receiver operating characteristic curve; AUC) [15]. Figure 10 displays the ROC curves and AUC scores of each model and displays differences in histogram distribution, with values of 0.97 and 0.96, respectively. In conclusion, model 2's performance is better than other models, with an outstanding AUC value of 0.98.

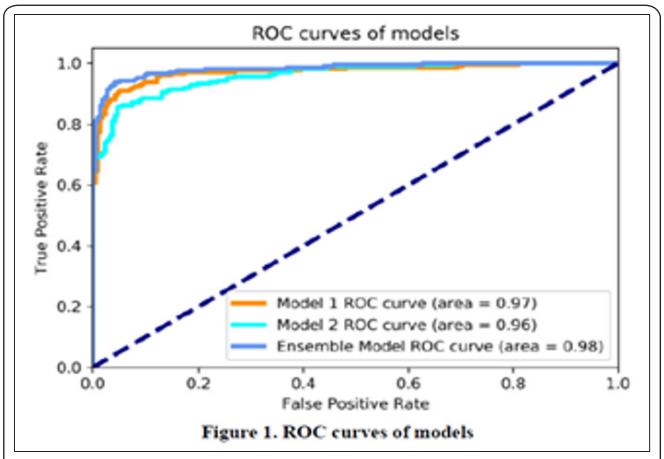



**Figure 10:** Shows ROC curves and AUC scores for each model.

## Phase 1 study

According to the statistical measurements made by the diagnostic tests of Phyathai 1 Hospital, Phyathai 2 Hospital, Paolo Phaholyothin Hospital, and Rajavithi Hospital, they've run an amount of experimentation for AI's capability testing to help diagnose pneumonia in patients who were infected with the Coronavirus disease 2019 and also had a positive RT-PCR swab.

From 210 CXR images in total, 101 images showed a true positive (same analysis from AI and radiologists: pneumonia detected), 22 images showed a false positive (pneumonia detected by AI only), 77 images showed a true negative (same analysis from AI and radiologists: pneumonia undetected), and 10 images showed a false negative (pneumonia detected by radiologists only).

According to results from a comparative test of CXR image analysis between AI and radiologists, matching diagnoses accounted for 84.76% (178 images), while unmatched diagnoses accounted for 15.24% (32 images). Other values are as follows: Sensitivity 0.9099 (90.99%), Specificity 0.7778 (77.78%), and Accuracy 0.8476 (84.76%).

Table 2 shows comparison in CXR image analysis between AI and radiologists from Phyathai 1 hospital, Phyathai 2 hospital, Paolo Phaholyothin Hospital, and Rajavithi Hospital. Diagnostic tests between AI and radiologists from Phyathai 1 Hospital, Phyathai 2 Hospital, and Paolo Phaholyothin Hospital have discovered that AI can detect pneumonia (38.2% of cases) and pneumonia with pulmonary tuberculosis (67.65% of cases), while radiologists can only detect pneumonia (28.09% of cases).

Figure 11 shows CXR image analysis from AI and radiologists (data collection: Phyathai 1 hospital, Phyathai 2 hospi-

**Table 2:** Shows comparison in CXR image analysis between AI and radiologists (DR) from Phyathai 1 hospital, Phyathai 2 hospital, Paolo Phaholyothin Hospital, and Rajavithi Hospital.

| | Pneumonia detected | Pneumonia undetected | Total amount | Percentage (%) |
|---|---|---|---|---|
| AI=DR | 101 | 77 | 178 | 84.76 |
| AI ¹DR | 10 | 22 | 32 | 15.24 |

tal, Paolo Phaholyothin Hospital). In addition, other diagnostic tests between AI and radiologist from Rajavithi Hospital also revealed that AI has the capacity to detect pneumonia (65.24% accounted for) and pneumonia with pulmonary tuberculosis (66.39% accounted for), while radiologists can only detect pneumonia (45.99% accounted for).

Figure 12 shows CXR image analysis from AI and radiologists (data collection site: Rajavithi Hospital). Efficacy values for an accurate pneumonia diagnosis: high performance AUC of 0.9878, sensitivity of 0.9717, and specificity of 0.9198.

## In conclusion for Phase 1 study

A comparison of diagnostic film analysis (in patients who were infected with Coronavirus disease 2019 and had a positive RT-PCR swab) between AI and radiologists from 4 hospitals: Phyathai 1 Hospital, Phyathai 2 Hospital, Paolo Phaholyothin Hospital, and Rajavithi Hospital, we've noticed some noteworthy details as follows:

False negative outcomes are resulting from some cases in which patients who have been fully treated came back to the hospital for a follow-up. AI was brought in for CXR screening, but the physician who was responsible for the case still gave the same treatment, referring to the previous diagnosis, which was based on the results of the initial CXR image analysis. This resulted in inaccurate interpretations, which made it necessary to repeat the diagnosis (re-diagnosis) in the patient. And false-positive outcomes result from the radiologist's misinterpretation.

Out of 210 CXR images, there were 32 mismatches (15.24%) in pneumonia diagnosis between AI and radiologists, which counted as statistically significant. It has been proven that AI could be a great help in reducing diagnostic errors that may occur in the future.

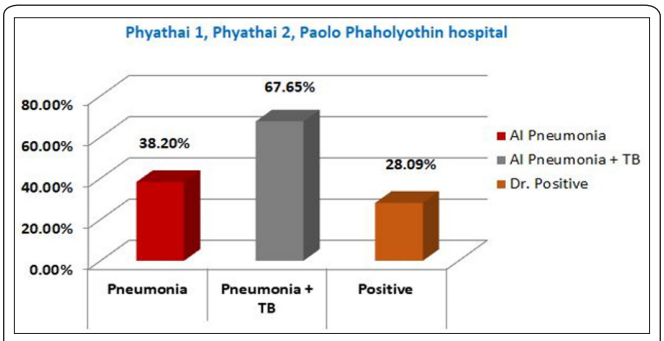



**Figure 11:** Shows CXR image analysis from AI and radiologists (data collection: Phyathai 1 hospital, Phyathai 2 hospital, Paolo Phaholyothin Hospital).

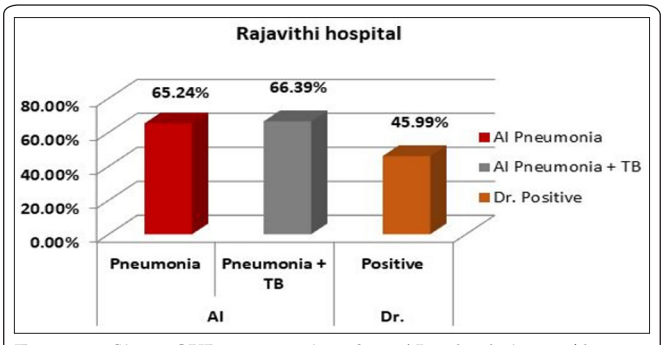



**Figure 12:** Shows CXR image analysis from AI and radiologists (data collection site: Rajavithi Hospital).

In a comparison of diagnostic film analysis between AI and radiologists, AI was able to detect pneumonia and pulmonary tuberculosis, which account for 67.65% of cases among patients at Phyathai 1 Hospital, Phyathai 2 Hospital, Paolo Phaholyothin Hospital, and 66.39% of cases among patients at Rajavithi Hospital. While radiologists were able to detect only pneumonia, in which 28.09% and 45.99% are accounted for, this demonstration displays the great capability of AI in screening and analyzing CXR images. When results are combined with other diagnostic tests run by physicians, it will be possible to prescribe a proper treatment for pulmonary tuberculosis along with pneumonia. A specific treatment that comes from precise and rapid analysis will provide maximum benefit for all patients.

## Phase 2 study

According to the process of CXR image analysis between AI and radiologists, we have received 1,100 images in total from 4 hospitals: 328 images were from Phyathai 1 Hospital (29.82%), 399 images were from Phyathai 2 Hospital (36.27%), 198 images were from Paolo Phaholyothin Hospital (18.00%), and 175 images were from Rajavithi Hospital (15.91%). 1034 images were shown as positive (94.0%), and 66 images were shown as negative (6.0%). Therefore, the diagnostic test comparing AI and radiologists revealed 94% accuracy and was proven to be rapid and effective.

Table 3 shows paired samples T-test results, comparing the mean value interpretation of CXR images (pneumonia) between AI and radiologists. Table 4 shows paired samples T-test results, showing differences in CXR images (pneumonia) interpretation between AI and radiologists. AI has an average of 0.94, while a radiologist has an average of 1.00. This value can be analyzed in t = -8.375 and Sig.000** (less than 0.05) means an interpretation between AI and radiologists is statistically significant due to results from a comparative CXR analysis (pneumonia) in a group of samples.

## In conclusion for Phase 2 study

A comparison of diagnostic films analysis (in patients who have pneumonia) between AI and radiologists from 4 hospitals (Phyathai 1 Hospital, Phyathai 2 Hospital, Paolo Phaholyothin Hospital, and Rajavithi Hospital), we've noticed some noteworthy details as follows: In a comparison of diagnostic film analysis between AI and radiologists, its analytic efficiency was found to be rapid and 94% accurate. The final diagnosis

**Table 3**: Shows paired samples T-test results, comparing the mean value interpretation of CXR images (pneumonia) between AI and Radiologists.

| Paired samples statistics | | | | | |
|---|---|---|---|---|---|
| | | Mean | N | Std. Deviation | Std. Error Mean |
| Pair 1 | AI Result | 0.94 | 1100 | 0.238 | 0.007** |
| | Radiologist Result | 1 | 1100 | 0 | 0.000*** |

**Table 4:** Paired samples T-test results, showing differences in CXR images (pneumonia) interpretation between AI and radiologists.

| Paired Samples Test | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paired differences | | | | | t | df | Sig. (2-tailed) |
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | AI Result-Radiologist Result | -0.06 | 0.238 | 0.007 | -0.074 | -0.046 | -8.375 | 1099 | 0.000** |

of pneumonia was not only based on CXR image analysis but also on other laboratories results and the initial diagnosis of the responsible physicians. AI's result had a mean value of 94, while a radiologist's had a mean value of 1, resulting in a statistically significant difference.

Some unmanaged situations, such as patients who have been fully treated, came back to the hospital for a follow-up. AI was brought in for CXR screening, and the result came out undetectable. But the physician who was responsible for the case still gave the same treatment, referring to the previous diagnosis based on the results of the initial CXR image analysis. This resulted in uncorrelated interpretations (a false negative). Given the circumstances, the suggested solution for this problem should be done by selecting groups of samples that currently display pneumonia's symptoms. Then the result from the CXR image analysis would be a true positive.

### Phase 3 study

According to this study group of 11,571 samples, they are collected from: Lopburi province (4,594 samples), Phetchaburi province (352 samples), Pathum Thani province (2,646 samples), Phyathai-Paolo Medical Campus (PMC) group (Phyathai 1 Hospital, Phyathai 2 Hospital, Paolo Phaholyothin Hospital), 2,897 samples, Rajavithi Hospital (1,000 samples), and SPE Tower (82 samples).

The analysis results of CXR images run by AI were noticed. Pneumonia was detected in 317 samples from Lopburi province (positive). 4,277 samples from Phetchaburi province were positive for pneumonia, while 317 samples were undetected (negative). 667 samples from Pathum Thani province were positive for pneumonia, while 1,979 samples were undetected (negative). Pneumonia was detected in 407 samples from the Phyathai-Paolo Medical Campus (PMC) group, while the remaining 2,490 samples were undetected (negative). 11 samples from the Rajavithi Hospital Group were detected as positive, while the other 989 samples were undetected (negative). Pneumonia was detected in 11 samples from the SPE tower (positive), while the remaining 71 samples were undetected (negative). From 11,571 CXR images (100%) that had been analyzed by AI, 1,628 images (14%) displayed a positive sign (analysis from AI: pneumonia detected), whereas 9,943 images (86%) displayed a negative sign (pneumonia undetected). And with real-time PCR technique, 19 samples (0.16%) were discovered to have Coronavirus disease 2019 infection, while 11,552 samples (99.84%) were undetected with the disease (Figures 13 and Figure 14).

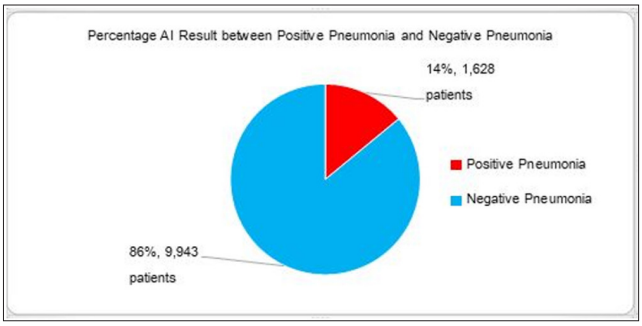



**Figure 13:** AI's result in pneumonia detection (Percentage).

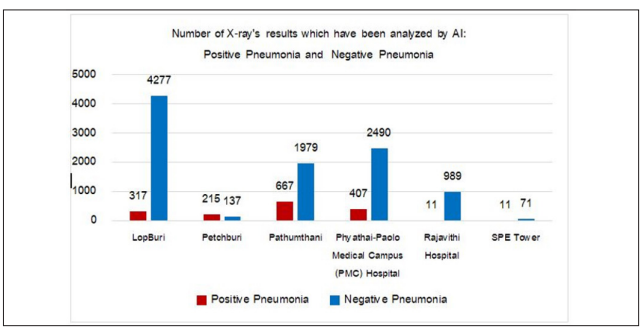



**Figure 14:** Number of CXR images that have been analyzed by AI: Positive pneumonia and negative pneumonia.

### In conclusion for Phase 3 study

Our studies revealed that there were statistically significant differences in the comparative test (pneumonia screening) between AI and radiologists for the further application of Coronavirus disease 2019 detection. There may be inaccuracies in the data's interpretation due to the current varieties of Coronavirus disease 2019 in patients. Some patients may not display symptoms, and some may have a higher risk of developing pneumonia later, e.g., the elderly, patients who have a history of respiratory disease (e.g., emphysema, asthma, or lung cancer), patients with underlying medical conditions that would increase the risk of developing pneumonia (high blood pressure, diabetes, heart disease, chronic renal disease), etc., which requires a number of processes to support further diagnosis. Continuation of this research is needed to make it possible to provide effective and accurate results that would allow patients to receive proper treatment in time.

## Discussion

By using AI combined with CXR image analysis (pneumonia) to screen out for Coronavirus disease 2019 infection,

there was proof that AI has the capability to diagnose other pathological diseases of the lungs in patients who are at risk of Coronavirus disease 2019 infection. Preparation of effective equipment and personal safety will reduce the risk of exposure to viruses. The availability of portable CXR machines based on machine power and mobility is also essential to establish operational guidelines and coordinate services. To alleviate potential concerns over AI's performance that could provide effective pathological diagnosis of lungs [21-25].

The availability of CXR image analysis in patients at risk of Coronavirus disease 2019 infection necessitates a certain level of expertise in this disease. To obtain data, one requires consideration of standard guidelines about protocols and service coordination as their main priority. Responsible agencies are required to pay attention to the safety of their workers to reduce their concerns and prevent virus outbreaks within organizations.

AI technology combined with CXR image analysis (pneumonia) is proven to be highly effective and easy to use to detect Coronavirus disease 2019 infection. Because it could operate through a digital system, which would provide all access to every difficult situation, such as the following: Due to an enormous number of patients who have a risk of coronavirus infection and require urgent screening and analysis, their numbers are exceeding the capacity of medical officers [26-30]. At remote medical facilities such as suburban hospitals, skilled radiologists became scarce. The prognosis of pneumonia's classification models in phase one was revealed by the dataset of AUC and ROC scores (area under the receptor functional curve: AUC) [15]. Model 1 and Model 2 show different types of histogram distribution values, which are 0.97 and 0.96, respectively. A combined model seems to have better performance than each model in action by having a value of 0.98 AUC (high performance AUC: 0.9878, sensitivity: 0.9717, and specificity: 0.9198).

Those details are related to a well-known study titled "A Multi-reader Evaluation of an Artificial Intelligence System," which was written by previous authors. Their experiment was based on chest radiographs, which were selected from Jeroen Bosch Hospital. And it seemed noteworthy that the interpretation efficiency of AI came up with 77% positive predictive value and 76% negative predictive value, while radiologist's results only showed 72% positive predictive value and 78% negative predictive value. This statistical similarity indicates satisfaction due to the results of this experiment.

The second phase's results indicate that AI could perform CXR image analysis with 94% accuracy that was proven to be rapid and effective.

During the third phase, 11,571 CXR images (100%) were collected and analyzed by AI. 1,628 images (14%) were displayed with a positive sign (analysis from AI: pneumonia detected), whereas 9,943 images (86%) were displayed with a negative sign (pneumonia undetected). And with real-time PCR technique, 19 samples (0.16%) were discovered to have Coronavirus disease 2019 infection, while 11,552 samples (99.84%) were undetected with the disease. This phase is correlated with known research titled "Computed Tomography for the Diagnosis of the COVID-19 Pandemic Crisis", written by previous researchers in the year 2020. Research explains as follows: From the end of 2019 until June 2020, the cumulative number of worldwide infections was about 7,600,000 cases and kept rising. During that time, Thailand also had more than 3,100 cases of its own. An effective vaccine that can prevent this hazard is still unavailable, and this virus has gone epidemic, making a huge impact in many aspects.

The Coronavirus disease of 2019 can be transmitted through droplet transmission (person to person) of infected patients through coughing or sneezing. It will affect the respiratory system, and later, the patient will develop symptoms of pneumonia. The best way to prevent this virus outbreak is to quickly screen and analyze people who have been exposed to Coronavirus disease 2019. By using effective methods, we can predict its pathological cycle from the beginning.

According to collective treatment data of patients who had been infected with Coronavirus disease 2019 in many countries, especially the People's Republic of China, lesions can be detected on chest computed tomography (CT) scans and by obtained results since the initial period using the standard real-time RT-PCR method for Coronavirus disease 2019 detection. And by looking at each unique lesion in the lungs (a white patch or opacity around the peripheral and lower segments of both lungs) that has been identified as a cause of Coronavirus infection, it would look promising. Therefore, medical examination procedures will be integrated with standard methods for Coronavirus disease 2019 detection and evaluation.

In addition, AI will be used to create a computer-assisted intelligent system. In order to improve chest CT's performance, to become more effective and skilled, and to alleviate the burden on radiologists, who are currently scarce in number. Throughout this third phase, pneumonia and pulmonary tuberculosis were also detected, and their severity was accelerating. There were 10 positive samples from nasopharyngeal swab tests for Coronavirus disease 2019 infection, while others (9 in number) were inconsistent. This could possibly be related to the new variants of Coronavirus disease 2019 that are currently spreading, such as the alpha variant or variant B.1.1.7 lineage (GR, G), the beta variant or lineage B.1.351 (GH, G), and the delta variant or lineage B.1.617. Some patients may not display any symptoms (asymptomatic), which could provide further complications between the diagnosis processes.

Therefore, an interpretation of results from only CXR images and a nasopharyngeal swab will be insufficient, which means other beneficial factors such as a thorough history or laboratory results, etc., are required. It's necessary to make sure this study could go further in order to provide a more effective and accurate result, which would alleviate the burdens on responsible doctors in screening and analyzing the disease.

To acknowledge AI's efficacy according to a comparative test of CXR image analysis between AI and a radiologist, this will allow patients to receive faster and proper treatment. This study was correlated with known research named "Development and evaluation of an artificial intelligence system for COVID-19 diagnosis", written by previous researchers in the

year 2020. In their research, they've been using the cohort test method and divided it into three groups based on different variables as follows: pneumonia vs. non-pneumonia, community-acquired pneumonia vs. Coronavirus disease 2019, and influenza vs. Coronavirus disease 2019—to analyze the differences between Coronavirus disease 2019 and other viruses. According to the comparative test between the AI system and radiologist, results showed that the AI system was more superior in distinguishing between non-viral community-acquired pneumonia and Coronavirus disease 2019, and between Influenza types A and B with Coronavirus disease 2019.

This satisfaction result was confirmed by the average of the time for interpreting (screening and analyzing) analytic data between the AI system and radiologists. The radiologist took approximately 6.5 minutes, while the AI system only took 2.73 seconds, proving that AI could assist radiologists with both qualitative and quantitative performance. And it's been noticed that most radiologists use typical macro-level radiology features to aid in the diagnosis process, which increases the likelihood of slice error prediction [31-].

## Expected outcome

1. To limit the Coronavirus disease 2019 outbreak in each locality, AI can be used as effective equipment for urgently screening and analyzing groups of at-risk people who have been exposed to Coronavirus disease 2019. One of the many benefits patients will gain from its assistance is that they could get a rapid transfer for hospital admission in time. Besides, it would alleviate the burden on responsible doctors, who currently work at both inside and outside hospitals across 77 provinces in Thailand.

2. To create a technological advantage point and create a competitive environment among other competitors, such as well-known business organizations. Our business alliances are shared with long-term investment by developing an infrastructure-as-a-service and software system via the internet (Software-as-a-Service).

3. To establish standards for the adoption of AI technology and to provide healthcare services throughout our country (Thailand) from the year 2020 onwards. To create a combination of experience and expertise with AI's application in the public health field as a medical device. It could be used to provide public health services for our business partners (agencies), with no charges for a 10-month period.

4. In a field of Thailand's medical services, AI could be applied for screening and analyzing causes of pneumonia other than the 2019 Coronavirus disease infection, which is only 1 of 15 diseases and conditions that can be analyzed by AI from CXR images.

## Limitations of this study

By using AI combined with CXR machines for screening coronavirus disease 2019 infection, our research team has noticed some errors such as pneumonia detection from unknown causes as follows:

- Breast augmentation by silicone insertion.
- By wearing an underwire bra.
- Lesion such as bruises on the surface of the breast (resulting from trauma).

Therefore, it is necessary to make sure this study can go further to provide a more effective and accurate result. This technology could potentially provide significant time savings for medical processes such as screening and analyzing patients who have a risk of Coronavirus disease 2019 infection, alleviating burdens on all hardworking medical staff.

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