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Evaluation of efficiency of artificial intelligence for chest radiograph interpretation for pulmonary tuberculosis screening in mobile x-ray vehicle

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ABSTRACT

Background: Tuberculosis (TB) is one of the major global health threats. The chest radiograph (CXR) is one of the primary tools for detecting TB, especially pulmonary TB. Artificial Intelligence (AI) is increasingly used with radiological technology by developing AI software for health screening by CXR.

Objectives: To compare the pulmonary TB screening results between the radiologist and AI software from the mobile x-ray screening vehicle of the Faculty of Allied Health Sciences, Thammasat University.

Materials and methods: 449 patients (408 normal, 41 abnormal) were exposed for chest radiograph at the mobile x-ray screening vehicle of Faculty of Allied Health Sciences, Thammasat University. The retrospective data was randomly collected between 2016 and 2018. The methods were divided into three steps: quality control for the x-ray machine, transferring the radiograph from digital radiography to PACS and AI, and displaying the results on the monitor with the StatPlus program.

Results: The mobile x-ray machine has passed the quality control test. In addition, the TB interpretation by AI showed Area Under Curve of 0.859 and the study demonstrated high specificity of 0.995 but low sensitivity of 0.722. The positive predictive value (PPV) was 0.951, which was less than the Negative Predictive Value of 0.963.

Conclusion: Artificial intelligence is becoming a healthcare supporter to help radiologists analyze and interpret chest radiographs and provide a fast diagnosis.

Introduction

Tuberculosis (TB) is a major global health threat, and the World Health Organization (WHO) estimates that Thailand is one of the 14 countries in the world with a TB prevalence in 2018.[1] The chest radiograph (CXR) is one of the primary tools for detecting TB, especially pulmonary TB because CXR has a high sensitivity for pulmonary TB. However, CXR has poor specificity.[2] Therefore, TB screening should always be made on TB diagnosis on bacteriological confirmation (sputum-smear microscopy or a molecular test). During the check-up, a chest radiograph in the posteroanterior view is usually taken. The patient is breast-attached with a cassette and the hand is on the patient's hip to separate the scapular from the lung. To reconstruct a chest radiograph, the patient needs to take a deep breath and hold it during the x-rays to reduce motion. The right technique should be good exposure, no rotation of the patient, and ensure patients are at the right marker. Airways should be without any deviation, centrally located in the radiograph and the angle at the carina should be less than 90 degrees. Bones and soft tissue have the ability to count the number of ribs (10 ribs posteriorly and 6 ribs anteriorly) and check the bone's lucency, bone opacity, and vertebral bodies. Cardiac size should not be more than half the size of the thorax. We should check the diaphragm to see if the left side is higher than the right side, the availability of air below the diaphragm, any gastric

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bubble, and the Costophrenic and Cardiophrenic angles. Lung fields should be uniform or have some opacities or lucencies. Appearance of pulmonary tuberculosis on the radiograph contains small opaque spots throughout the lungs and enlargement of a hilar region in early stages or regions of calcification with cavitations which is frequently in the area of upper lobes and apices with upward retraction of hila.

Artificial intelligence (AI) often instantiated as software programs is a branch of computer science that attempts to understand and build intelligent entities. The subset of AI is Machine learning (ML) and the subset of ML is Deep learning (DL). AI in clinical practice can be used for interpreting patient genomes, treatment selection, automated surgery, and disease diagnosis.[3] Nowadays, Artificial Intelligence is increasingly employed with radiological technology by developing AI software for health screening by CXR. Most of the x-ray machine vendors have launched the AI section in x-ray machines such as FDR AQRO mini mobile system from FujiFilm,[4] Ysio X.pree from Siemens,[5] ALND from Samsung for lung nodule detection, etc. [6]

The purpose of this study is to compare the pulmonary TB screening results between the radiologist and AI software from the mobile x-ray screening vehicle of the Faculty of Allied Health Sciences, Thammasat University.

Materials and methods

This research is based on a retrospective descriptive study. 449 patients (408 normal, 41 abnormal) were exposed by x-ray for chest radiograph at the mobile x-ray screening vehicle of the Faculty of Allied Health Sciences, Thammasat University. This research recording was approved by the ethical review sub-committee board for human research involving sciences, Thammasat University, No.3 and the approval code is COA No.017/2563. The retrospective data was randomly collected between 2016 and 2018. The methods were divided into 3 steps, namely quality control for the x-ray machine, transferring radiograph from digital radiography to Picture Archiving and Communication System (PACS) and AI, displaying results on a monitor.

The X-ray machine in the mobile vehicle (GEMSS, TITAN 2000, No.793291105153, Korea) was subjected to quality control, which includes general checklist, the general condition of medical and electrical components, motion and lock check, target to film distance indicator check, field size indication, congruence of light and radiation fields, cross hair centering, focal spot size, exposure consistency, timer accuracy, mA or mAs linearity, kVp linearity, and automatic exposure control.[7]

The image was obtained from a modality, which is a digital radiography system. Then, the image was sent to PACS and AI engine (Manage AI, Internet Thailand Public Company Limited, Thailand) to analyze the results as shown in Figure 1 and the percent below the red box is the accuracy of AI for this radiograph. This program was tested for tuberculosis detection which obtained an accuracy, sensitivity, and specificity of 96, 96, and 95 percent, respectively. The system has detected and characterized the exam for suspected tuberculosis. The result displayed an alert message from the AI engine to PACS with the information, identification, and graphics highlighting abnormalities. The TB cases, which were detected by AI, will be flagged and prioritized for expedited reading in the worklist within 10 seconds. Then, the chest x-ray results from the radiologists (2 and 10 years of clinical experience) and AI program results were compared. The data was analyzed by StatPlus (Build 7.3.3/Core v7.3.32, AnalystSoft Inc., USA). The tuberculosis detection performance was assessed using Receiver Operating Characteristics (ROC) analysis and area under the curve (AUC). The data was validated by calculating the specificity, sensitivity, and positive predictive value (PPV).

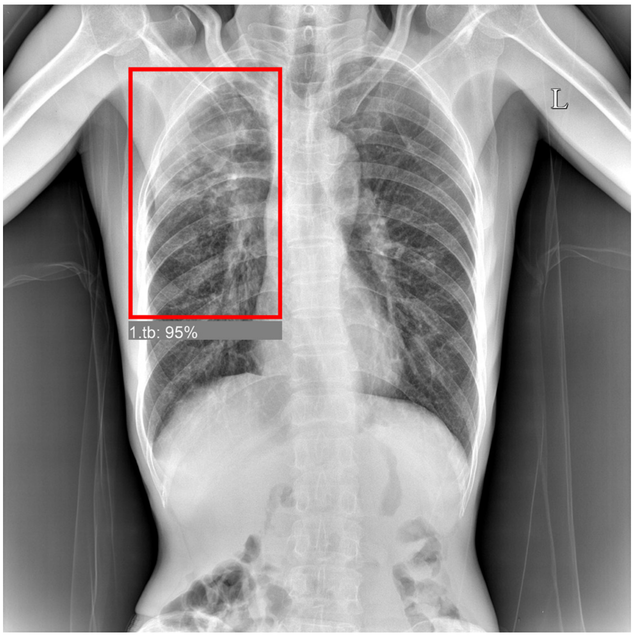

***Figure 1**. Result of AI interpretation.*

Results

Quality control of mobile x-ray machines was composed of the following sections. First, the physical test of the machine was passed. The congruence of Source to Image Distance (SID) between the set value and measurement was correlated. The movement and lock system were tested. It can only move up and down and can lock automatically. The light intensity from the x-ray tube was less than 100 lux in every area. Exposure reproducibility was passed because the coefficient of variation (CV) was 0.035 which was within 0.05 limit. Time reproducibility was 0.004% of CV that was within the limit of 5%. Also, time accuracy was passed (within the limit of 10% error).[7] The kVp reproducibility was passed because it is very precise and had no deviation. The kVp accuracy and mAs linearity are still within the limit.

Image quality was passed that included central beam alignment, dynamic range, special resolution, contrast resolution, homogeneity as demonstrated in Figure 2. The misalignment of the light and x-ray field is acceptable (within 2% of SID). When the x-ray machine is checked by testing, it can be used for the examination accurately.

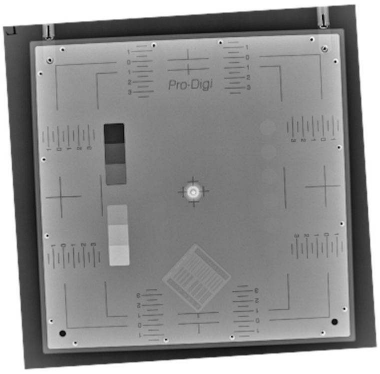

***Figure 2**. Image quality of x-ray machine using Pro-Digi, Raysafe.*

The final step was to analyze the data set using the StatPlus program, and the result showed that the AUC was 0.859, as shown in Figure 3. Also, the study demonstrates that the TB interpretation by AI was high specificity (0.995) but low sensitivity (0.722) because the number of tuberculosis cases was small as demonstrated in table 1. Table 2 showed that the Positive predictive value (PPV) was 0.951, which was less than the Negative predictive value (0.963). Therefore, the TB diagnosis by AI is accurate and precise as the gold standard is the radiologist's interpretation.

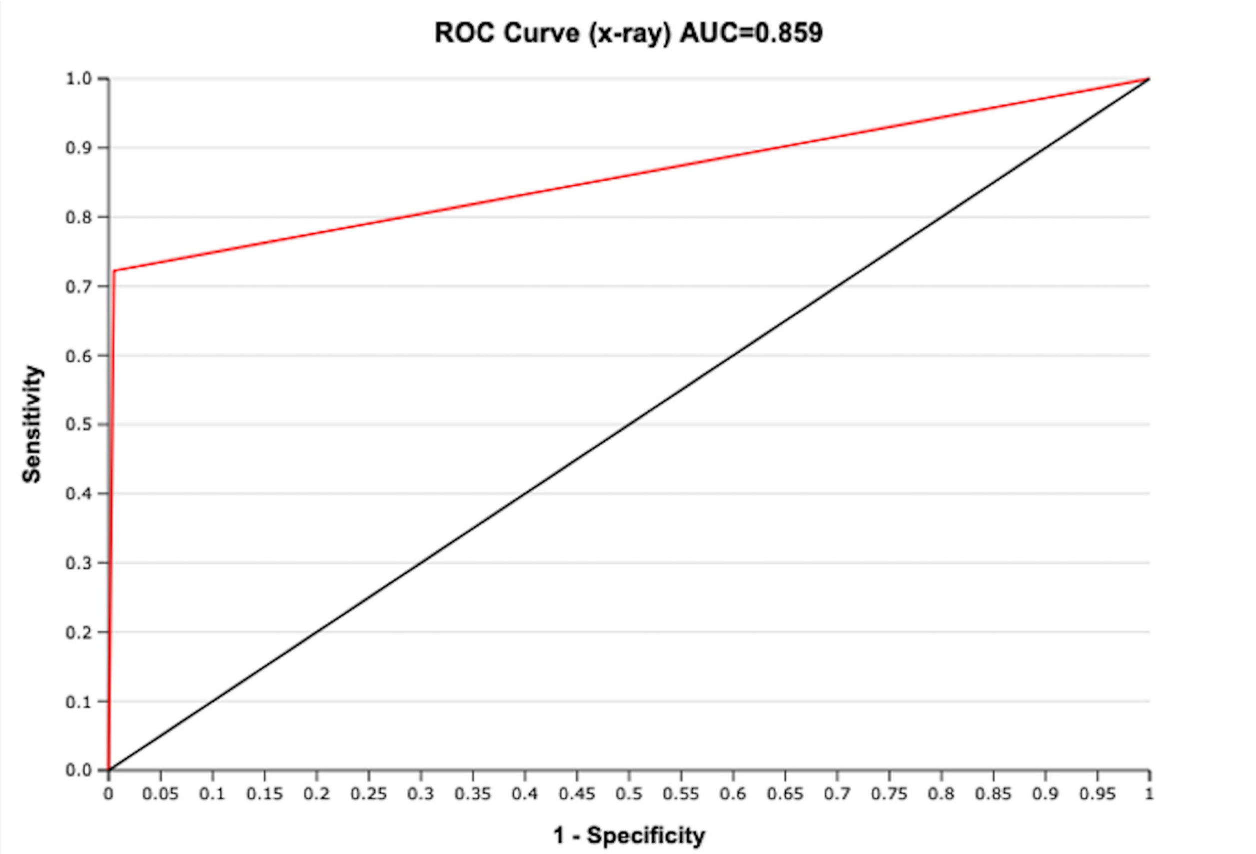

***Figure 3**. ROC on a test set of 449 CXRs.*

Table 1 Number of cases in this study.

Result	Number of TB cases	Number of normal cases	Total patient
Radiologist	41 (9.13%)	408 (90.87%)	449
Artificial Intelligence	54 (12.03%)	395 (87.97%)	

Table 2 Performance indices from this study.

	Performance indices
Sensitivity	0.7222
Specificity	0.9949
Accuracy	0.9621
Positive predictive value	0.9512
Negative predictive value	0.9632
True positive	39
True negative	393
False-positive	2
False-negative	15
Positive Likelihood Ratio	142.64
Negative Likelihood Ratio	0.28

Discussion

The radiologists who interpreted chest radiographs have approximately 6 years of experience. From this study, the sensitivity of the AI program was 0.722 and specificity was 0.995. The specificity was higher than sensitivity. Therefore, TB patients will be detected correctly. Area under the curve was 0.859, which is more than the computed aid detection (CAD) (AUC=0.71-0.75).[8] While in other research, Hwang., et al.[9] found that tuberculosis can be detected (AUC=0.988) by using the 450 Korean data sets (300 normal, 150 tuberculosis). The result was excellent because of the validation by a group of thoracic radiologists and a variety of sample sizes. Moreover, Muyoyeta M., et al.[10] found that tuberculosis detection by deep learning (AUC=0.82) was a better result than Computer Aid Detection (AUC=0.71-0.75). In the research of El-Solh A. et al.,[11] an artificial neural network (ANN) was developed using clinical and radiographic information to predict active pulmonary TB and found that the accuracy of the model was 0.923±0.056 from 119 patients formed the validation set. Lakhani P. et al.,[12] studied in AI for Pulmonary Tuberculosis diagnosis from CXR using AlexNet and GoogLeNet. They found that AUC was 0.99 had 97.3% sensitivity, and 100% of specificity. Rapurkar P. et al.,[13] used Deep Learning (CheXNeXt) for atelectasis detection (AUC=0.862), and radiologists' AUC was 0.808. The radiologist spent more time for interpretation. Moreover, Steiner A. et al.,[14] found that software CAD4TB can evaluate chest radiographs from an asymptomatic prison population (AUC=0.75) on the superset of 1321 radiographs in a short time. The finding in this research suggests that radiologist interpretation is still the first choice for accurate chest x-ray diagnosis, but AI can be supported as well as it can interpret chest x-ray faster.

The major limitation of this study is that instead of using mycobacterial culture, we have used the chest x-ray result from a radiologist which we do not know whether the patients have Tuberculosis or not. Also, the artifact in the chest radiograph can lead to AI misinterpretation such as the screen shirt or button which are usually found in the patient's body at the check-up center as shown in Figure 4. Moreover, the number of tuberculosis cases is small, which affects the sensitivity in this study.

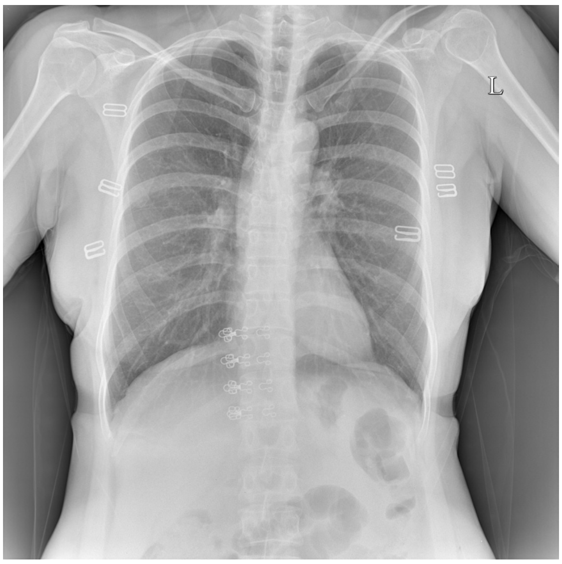

Figure 4. *Chest radiograph with artifacts.*

Conclusion

Artificial intelligence is becoming a healthcare supporter to help radiologists quickly interpret chest radiographs and provide a fast diagnosis. However, some artifacts in the film such as metal artifacts can make AI give misleading results. Therefore, patients should change their dress to a hospital gown and remove the accessories before having a chest x-ray. However, AI is good for TB screening and there are many publications for Covid-19 primary screening but the gold standard is still the swap test and CT scan. AI has many benefits for medical diagnosis, but we still have to do a second check to validate the results.

Conflict of interest

The author declare no conflicts of interest.

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