Abstract

**Background:** It is of critical importance to improve and maintain the quality of chest radiography (CXR) to avoid faulty diagnosis of respiratory diseases. The study aims to determine the effectiveness of a training program in improving the quality of CXR among radiological technologists (RTs) in Laos. **Design:** This was a cross-sectional study, conducted through on-site investigation of X-ray facilities, assessment of CXR films in Laos, both before and after a training course in November 2013. **Methods:** Each RT prospectively selected 6 recent CXR films, taken both before and within approximately 6 months of attending the training course. Consequently, 12 CXR films per RT were supposed to be collected for assessment. The quality of the CXR films was assessed using the “Assessment Sheet for Imaging Quality of Chest Radiography.” **Results:** Nineteen RTs from 19 facilities at 16 provinces in Laos participated in the training course. Among them, 17 RTs submitted the required set of CXR films (total: 204 films). A wide range of X-ray machine settings had been used as tube voltage ranged from 40 to 130 kV. The assessment of the CXR films indicated that the training was effective in improving the CXR quality regarding contrast ($P = 0.005$), sharpness ($P = 0.004$), and the total score on the 6 assessment factors ($P = 0.009$). **Conclusions:** The significant improvement in the total score on the 6 assessment factors, in contrast, and in sharpness, strongly suggests that the training course had a positive impact on the quality of CXR among a sample trainees of RTs in Laos.

**Keywords:** Assessment, chest, health system, radiography, tuberculosis

**Introduction**

Chest radiography (CXR) is used mainly to diagnose a wide range of respiratory diseases, including pulmonary tuberculosis (PTB). While CXR is a sensitive tool for detecting abnormal lesions in the lung field, it is considered a nonspecific technique for diagnosing PTB.[1,2] The National Tuberculosis Control Program (NTP) in Laos recommends that CXR is used as a secondary tool in the diagnosis of PTB patients with negative sputum examination results.[3]

A CXR of unsatisfactory quality may result in either over- or under-diagnosis of PTB, both of which have serious consequences. Overdiagnosis of PTB can lead to unnecessary treatment with antituberculosis agents, putting the patient at risk of drug-related adverse effects, including illness and death.[4] Underdiagnosis of PTB may delay in diagnosis, resulting in further disease progression and the spread of the bacilli to other people, thereby hampering public health control of TB in the community. Thus, it is critical to improve and maintain the quality of CXR to avoid inaccurate diagnoses of PTB.

To address the problems associated with the quality of CXR, the Research Institute of Tuberculosis (RIT)/Japan Anti-Tuberculosis Association (JATA), Kiyose, Japan, took the lead in close collaboration with the agencies involved in the Tuberculosis Coalition for Technical Assistance (TBCTA), developed a handbook on quality assurance for CXR in 2008.[5]
Based on the contents of this handbook, its authors have so far conducted a series of training courses in African and Asian countries. In addition, operational research to evaluate the effectiveness of the training course for 40 radiological technologists (RTs) was organized in the Philippines, from 2009 to 2010, as reported previously. That study showed significant improvements in the total score of assessment factors, which suggested that the training course had a positive impact on improving the quality of CXRs. Indeed, the follow-up study found that the positive impact persisted at least 3 years after the completion of the training course.

Our study aimed to describe the present practices in CXR at the government X-ray facilities in Laos and to determine the short-term effectiveness of quality assurance training for RTs using CXR for the diagnosis of PTB. The hypothesis of this study is that quality assurance training for RTs in Laos significantly improves the CXR quality.

**Methods**

The present study had a cross-sectional design, and data were collected through on-site investigations of government X-ray facilities, interviews of RTs, and reviews of CXR films. The government X-ray facilities and RTs were selected by the Laos NTP. The Laos NTP, in collaboration with the WHO Regional Office for the Western Pacific, conducted a 4-day training course in Vientiane, for RTs in November 2013. It covered the same topics as the training course conducted previously in the Philippines: (1) the role of CXR for TB diagnosis in the NTP, (2) the basic concepts related to the quality of CXRs, and (3) individual practices for CXR imaging quality using the assessment sheet developed by the TBCTA. Two senior RTs (MM and TD) led and facilitated throughout the training course.

The data were collected using a semi-closed questionnaire form that was divided into 2 parts. One part was completed by the RTs at the X-ray facilities, which required them to fill in information such as the facility's profile, brief description of the facility’s X-ray equipment, and current practices on the taking and processing of CXR films. This form was filled in by the RTs before the training course. The second part was intended for 2 CXR film performance assessors (TD and MM). Each RT prospectively selected 6 recent CXR films (3 of male patients and 3 of female patients, all 15 years of age or older) before the training course and another 6 within approximately 6 months of attending the training course. Consequently, 12 CXR films per RT were expected to be collected for assessment. One investigator (AO) randomly mixed all the collected pre- and post-training CXR films, masked the institution name and date of the film, and forwarded them to the 2 assessors (TD and MM) for independent, blinded assessment. Even though the assessors were well trained and well experienced to the assessment criteria, variations in rating scores were inevitable. A final score was determined by consensus between the 2 assessors, particularly in cases for which their scores did not agree. The quality of CXR was assessed using a 6-item quality factor scoring system, as described previously: 1) identification marks, 2) patient positioning, 3) density, 4) contrast, 5) sharpness, and 6) artifacts. Each of the factors was graded numerically, with 1 for “good”, 2 for “fair”, and 3 for “poor”; factor 6) was scored as 1 for “none”, 2 for “slight”, and 3 for “present”. The sum of the scores for the 6 assessment factors was determined as the total score and further categorized as the assessment result with 1 for “excellent” (≥7); 2 for “good” (6–11, with no score of 3); 3 for “fair” (5–13, with one or two scores of 3); and 4 for “poor” (≤4). The total scores of each of the 7 items for patient positioning assessment and of the 4 items for both density and contrast were also calculated. We compared each of the total quality scores between the assessment points (i.e., pre- and post-training course). The scores were divided into quartiles, and the differences in total scores were analyzed with the Wilcoxon matched pairs test using STATA ver. 13.1 (StataCorp LP, College Station, Texas, USA) for statistical analysis. P < 0.05 was considered to be statistically significant. Weighted Cohen’s kappa values rated by the 2 assessors were calculated for all of the assessment scores except identification marks.

The RTs obtained documented informed consent forms from each patient who released their CXR films for this assessment. The study protocol was approved in advance of the study by both the National Ethics Committee for Health Research of the Ministry of Health in Laos (No. 60/2013) and the Institutional Review Board of the RIT in Japan (RIT/IRB 25-21).

**Results**

Nineteen RTs from 19 facilities in 16 provinces in Laos participated in the training course. Among them, 17 RTs submitted the required set of CXR films (total: 204 films). Two participants were excluded due to no or incomplete submission of CXR films.

All X-ray facilities investigated used analog system X-ray machines. Among the 17 facilities, only 8 facilities had installed automatic film processors. It was immediately apparent that there was a wide range of X-ray machine settings; tube voltage ranged from 40 to 130 kV, tube current from 50 to 500 mA, and exposure time from 0.01 to 0.6 s [Table 1]. Only 3 X-ray facilities (facilities 11, 13 and 16) fully used the recommended values from the TBCTA handbook. Most X-ray facilities tended to meet the recommended values in both “distance between tube focus and X-ray film” (15 facilities [88.2%]) and “tube current” (14 facilities [82.4%]) and to not meet the values for either “tube voltage” (8 facilities [47.1%]) or “exposure time” (8 facilities [47.1%]).

The 2 investigators (MM and TD) independently assessed the 204 CXR films (a mix of pre- and post-training films) and generated final scores for each of the 6 assessment factors after a thorough discussion regarding discrepant scores. The weighted Cohen’s kappa values for each of the scores rated by the 2 assessors before reaching the final agreement scores
were 0.61 \( (P < 0.001) \) for patient positioning, 0.11 \( (P = 0.009) \) for density, 0.58 \( (P < 0.001) \) for contrast, 0.47 \( (P < 0.001) \) for sharpness, and 0.73 \( (P < 0.001) \) for artifacts.

The assessment of the CXR films indicated that the training was effective in improving performance in contrast \( (z = 2.80; P = 0.005) \), sharpness \( (z = 2.89; P = 0.004) \), and total sum score of the 6 assessment factors \( (z = 2.63; P = 0.009) \) [Figure 1]. The training was not shown to be completely effective in improving other assessment factors, such as proper identification marks, patient positioning, density, artifacts, and assessment result although the training led to some improvement in both identification marks \( (z = 1.84; P = 0.07) \) and assessment result \( (z = 1.89; P = 0.06) \).

The sum score for patient positioning did not show significant improvement; however, one of the 7 items for the patient positioning (“asymmetric density of lungs”) showed significant improvement \( [z = 2.0, P = 0.046, \text{Figure } 2] \). Likewise, 3 of the 4 items for density (“lung periphery,” “mediastinum,” and “cardiac shadow”) showed significant improvement \( (z = 2.04, P = 0.04; z = 2.01, P = 0.04; \text{and } z = 2.39, P = 0.02, \text{respectively } [\text{Figure } 3]) \). Correspondingly, 2 of the 4 items for contrast (“mediastinum” and “cardiac shadow”) also showed significant improvement \( (z = 1.97, P = 0.048; z = 2.37, P = 0.02, \text{respectively } [\text{Figure } 4]) \).

**D**iscussion

To the best of our knowledge, this is the first report examining the effectiveness of a quality assessment training course for CXR in Laos based on the TBCTA handbook.[9]

As expected, we found a wide range of X-ray machine settings and relatively poor compliance with both the “tube voltage” and the “exposure time” values recommended by the TBCTA handbook. This observation is in line with similar findings among X-ray facilities in the Philippines.[10] However, data collected approximately 3 years after the completion of the training course from the same X-ray facilities in the Philippines, indicated significant improvement in compliance with the recommended values for both settings.[9] Hence, we expect similar improvement over time in Laos although we were unable to address this issue in the present study.

Utilizing the handbook’s assessment sheet, we observed that only 2 assessment factors (contrast \( P = 0.005 \) and sharpness \( P = 0.004 \)), in addition to the total sum score on the 6 assessment factors \( P = 0.009 \), showed significant improvement from the pretraining assessment to the posttraining assessment. The median sum of the scores for identification marking seemed to improve drastically, from 18 to 12, as indicated in Figure 1, although the difference did not reach statistical significance, most likely due to the wide interquartile range of the sum of the scores. The previous study, conducted in the Philippines with 40 RTs, found significant improvement in this assessment factor,[8] which suggests that the training may have shown greater effectiveness in improving identification marking in our study as well if we had been able to enroll more RTs.

Further, one of the 7 items for patient positioning (“asymmetric density of lungs”) showed significant improvement, although the sum of the scores for patient

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**Table 1: Essential characteristics of government X-ray facilities and settings of X-ray machines for chest radiography before the training course on quality chest radiography, in 2013, Lao PDR**

| Facility serial number | Average number of CXRs/day (a) | Distance between tube focus and X-ray film (cm) | Tube voltage (kV) (100-120 kV)* | Tube current (mA) (≥100 mA)* | Exposure time (s) (<0.05 s)* | Film processor |
|------------------------|-------------------------------|-----------------------------------------------|-------------------------------|-------------------------------|---------------------|---------------|
| 1                      | <10                           | 180                                           | 100                           | 100                           | 0.50                | Automatic      |
| 2                      | 10-19                         | 180                                           | 50                            | 50                            | 0.25                | Automatic      |
| 3                      | <10                           | 120-170                                       | 70                            | 60                            | 0.60                | Manual         |
| 4                      | 10-19                         | 140-200                                       | 120                           | 500                           | 0.30                | Automatic      |
| 5                      | 20 or more                    | 180                                           | 73                            | 200                           | 0.06                | Automatic      |
| 6                      | 10-19                         | 200                                           | 114                           | 320                           | 0.10                | Manual         |
| 7                      | <10                           | 180                                           | 85                            | 60                            | 0.02                | Manual         |
| 8                      | <10                           | 180                                           | 130                           | 200                           | 0.02                | Automatic      |
| 9                      | 10-19                         | 200                                           | 70                            | 250                           | 0.02                | Manual         |
| 10                     | 10-19                         | 180                                           | 80                            | 1                             | 0.03                | Automatic      |
| 11                     | <10                           | 180                                           | 120                           | 400                           | 0.03                | Automatic      |
| 12                     | <10                           | 140                                           | 40                            | 200                           | 0.02                | Manual         |
| 13                     | 20 or more                    | 180                                           | 120                           | 400                           | 0.03                | Automatic      |
| 14                     | <10                           | 150                                           | 120                           | 100                           | 0.05                | Manual         |
| 15                     | <10                           | 200                                           | 120                           | 400                           | 0.05                | Manual         |
| 16                     | 10-19                         | 180                                           | 120                           | 320                           | 0.01                | Manual         |
| 17                     | 20 or more                    | 180                                           | 90                            | 320                           | 0.09                | Manual         |

*Value(s) recommended in the Tuberculosis Coalition for Technical Assistance handbook,[5] distance between tube focus and X-ray film: 140-200 cm, Tube voltage: 100-120 kV, Tube current: ≥100 mA, Exposure time: <0.05 s, mA at facility number 10 was unavailable due to mobile X-ray unit.

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positioning did not show significant improvement. Similarly, 3 of the 4 items for density showed significant improvement, without significant improvement in the sum of the scores on density. One of the most important instructions during training with regard to improving the quality of CXR was to emphasize the advantage of higher voltage (kV) with shorter X-ray exposure time. The results showed that 3 of the 4 items for density and 2 of the 4 items for contrast indicated significant improvement. The improvements in these items were directly related to the advantages of higher kV. In addition, the improvement in sharpness depends on shorter X-ray exposure time. These findings suggest that the participants fully comprehended the key messages of the training and may have taken the necessary actions to adjust the X-ray exposure settings at their facilities following the training course.

This further suggested that the scoring system proposed by the TBCTA handbook was limited in its ability to show the impact of the training course on CXR quality improvement by comparing CXR quality before and after the training course. It may be better to examine each item in detail to better assess the effects of the training, rather than focusing on the sum of the scores only. This can be applied to the assessment scores in our study, which indicated significant improvement in factors such as contrast; i.e., 2 of the 4 contrast items indicated significant improvement. We thus need to carefully interpret the results obtained from this study.

In the present study, we applied the TBCTA handbook’s method to assess the quality of CXR. This assessment system
was developed during the annual CXR quality assessment meetings of the JATA[10] while, a similar scoring system was also developed by the European Commission.[11,12] In our study, the scores were determined by 2 senior well-experienced RTs (MM and TD), who assessed the quality of CXR in accordance with the handbook’s instructions. As the weighted Cohen’s kappa values of 5 assessment scores indicated from poor to substantial agreement between the 2 assessors, there existed variability between the assessors. To minimize human error and bias, we randomly mixed all of the CXR films and masked the X-ray facility names and film dates before they were given to the assessors. In addition, any discrepancies in the final assessment scores were discussed freely and resolved between the 2 assessors.

The present study was not designed to assess the contribution of the CXR quality improvement through the training course to the technical diagnostic quality of CXR reading by clinicians. Hence, it is impossible to provide any findings on the change of CXR reading comparing before and after the training course. Further study taking this important component into account may be expected to provide some insights on this.

One may argue that the introduction of the digital radiography system would eliminate technical problems regarding CXR quality. Indeed, the digital radiography system can drastically reduce the problems associated with CXR quality if used properly; for example, it provides adjustable images on density and contrast and eliminates the film development process. However, even the digital radiography system cannot exclude essential issues such as patient positioning and manipulation of X-ray factors, and it requires appropriate setting of the devices, such as high-quality computing systems and monitors.[13-15] Even with the aforementioned limitations and careful interpretation of the results of our study, we believe that it provides valuable findings regarding the training course of quality CXR using the TBCTA handbook in the context of Laos.

Conclusions

The significant improvement in the total score on the 6 assessment factors, as well as improvements in contrast and sharpness, suggests the positive impact of the training course for RTs in improving the quality of CXR in Laos. Therefore, we recommend that the Laos NTP, in close collaboration with concerned health sectors, expands this training course nationwide to improve the quality of CXR and to provide those in need with sound health services.

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Conflicts of interest

There are no conflicts of interest.

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