Conference Paper

Validation of Chest Radiograph Reading and Recording System (CRRS) in Three Sites in Indonesia

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Abstract

One of the main challenges in Tuberculosis (TB) management is the lack of tools for early and accurate diagnosis. Chest X-ray remains one of the most convenient ways for TB diagnosis. Even though chest X-ray result can be obtained quickly, it requires accurate interpretation from radiologist. Chest Radiograph Reading and Recording System (CRRS) can be used to standardize the interpretation process for TB diagnosis. This study aims to determine the validity of CRRS in hospital and primary health center. This is a cross-sectional observational study in Cipto Mangunkusumo Hospital, Jatinegara, and Matraman Healthcare Centers. The study was conducted from May to November 2015. Participants were recruited with consecutive sampling. The eligibility criteria were age ≥ 15 years old, new or previously treated patients with current TB treatment ≤ 1 months, and having symptoms consistent with TB, or having a contact history with patients with smear positive or having extra-pulmonary TB. Recruited patients underwent anamnesis, physical examination, morning sputum examination, and chest X-ray examination. Acid-fast bacilli smears and culture of the morning sputum was conducted in Microbiology Laboratory of Faculty of Medicine, Universitas Indonesia. Chest X-ray examination was conducted in Cipto Mangunkusumo Hospital. The radiologists filled the CRRS form that contains the scoring based on four features: Score 2 is given for Upper lobe large opacity (> 1 cm), cavity in any location, and adenopathy in any location, and score 1 for unilateral pleural effusion. The total number of the score was then categorized using different cut-offs (≥ 1, ≥ 2, ≥ 3, and ≥ 4) to evaluate the validity of the method compared with the sputum examination. Two radiologists read the same chest X-ray, and when there was a disagreement, a senior radiologist made the final decision. The agreement between the two radiologists was determined using the Cohen's kappa. As many as 210 chest Xx-ray results were read using CRRS method. The highest Cohen's Kappa coefficient between the two readers was 0.84 for large opacity feature, while the lowest was 0.52 for lymphadenopathy. The validity of the scoring with cut-off ≥ 1 showed the highest accuracy of 76% with sensitivity 76.2%; specificity 61.4%; positive predictive value 68.6%; and negative predictive value 63.6%. The lowest accuracy showed on the cut-off ≥ 3 and ≥ 4, with accuracy of 60.8%. On each radiological feature, the best accuracy (almost 80%) was showed by large opacity feature. The interpretation using CRRS method has good inter-reader agreement. On the other hand, the accuracy of the method for supporting tools in reading chest X-ray for suspected TB patients is lacking. However, we acknowledge that the conclusion may be biased due to the unmet target of number of participants recruited. Further investigation is needed to make definite conclusion.

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1. Introduction

Tuberculosis (TB) is global health Problem [1]. This disease causing death and has wide impact to economic situation and quality of life [2, 3]. Nowadays, the prevalence of Indonesian citizens whom diagnosed as pulmonary TB patients are 0.4 percent [4].

Tuberculosis controlling program aims to lower the morbidity and mortality and break the chain of transmission in the community. One of the DOTS strategy in the TB control program is the standardized short term medication to all TB cases [5]. One of the challenge is to increase the early detection of cases in healthcare facility (health centres/*Puskesmas*/PKM and hospitals).

In order to find or diagnose cases as early as possible, appropriate diagnostic tool is needed. Early diagnosis is crucial not only to determine the medication, but also to break the chain of transmission.

Pulmonary TB diagnosis is done based on clinical symptoms, Acid Fast Bacili (AFB) smear confirmed microscopically, culture of M. Tuberculosis, and chest X-ray [6]. AFB smear has several limitation. The sufficient amount of sputum is hard to get (5000 bacteria/ml sputum is needed), and about 50–100 bacteria/ml sputum is needed to confirm AFB smear positive microscopically and culture positive [7]. Moreover, it takes eight weeks to obtain culture examination result and not all hospitals have this kind of measurement [8]. Because of those conditions, the medication is often given before the culture result is obtained. Chest X-Ray is an important supporting tool in TB Early diagnosis. Although the result of Chest X-Ray can be obtained quickly, the interpretation could be influenced by several things. One of those things is the radiologist factor, in which the result can be subjective. Second, there is no specific form to read the Chest X-Ray which is easy to interpret. Sensitivity and specificity of the chest X-ray are 22% and 68% [9]. Chest X-ray validity result in the TB clinic in 2005 showed the sensitivity and specificity are 78% and 51% [10]. Due to the poor specificity, there are many false diagnosis.

Today there is more objective reading technique to interpret chest X-ray result using Chest Radiograph Reading and Recording System (CRRS) [11]. This system uses a designed form (attached) to read chest X-ray features in posteroanterior view. This method not only has good inter-reader agreement in interpreting chest X-ray between

the radiologists, but also has good intrareader agreement (increasing the reliability). Dawson et al. [12]. Developed it by adding scoring system and weighting on the reading result to be implemented clinically. This system can support the diagnosis of Pulmonary TB with negative AFB smear. However, it still needs to be tested further especially in the high prevalence region (100 cases/100.000 population) [13].

Findings from Health Facilities Research in 2011 stated that as many as 93.7% of government hospitals already have X-ray staff. Although there is no accurate data on radiologist's distribution in government hospitals, about 80% of government hospitals have main specialists: internists, pediatricians, obstetric specialists and surgeons [14, 15]. This findings can impact on the less optimal result of interpretation/reading of thoracic photograph which should be done by radiologist.

The result of Riskesdas 2013 shows that the prevalence of pulmonary tuberculosis in Jakarta (0.6%) is the third largest behind West Java (0.7%) and Papua (0.6%) [4]. The data obtained from the DKI Jakarta Health Office 2014, the total number of tuberculosis patients in Jakarta is 14,416 cases, the highest number comes from East Jakarta 4,666 cases, followed by Central Jakarta 3,188, and West Jakarta 3,046. South Jakarta 2,679 and North Jakarta 837. The highest number of TB cases in East Jakarta in 2014 was Jatinegara Sub-district Healthcare Centre with 450 cases of pulmonary tuberculosis. While in Matraman Sub-district Healthcare Centre 2014 there were 150 cases of tuberculosis per year with BTA positive 138 cases (report from the program caretakers of Jatinegara and Matraman Sub-district Healthcare Centre).

Investigation of thoracic photographs in people with suspected pulmonary TB is of great importance in assisting early diagnosis of TB. Before the system of reading and recording of thoracic photo (CRRS) results can be widely used, it is necessary to conduct a validity test and compare it with the result of sputum culture as gold standard.

2. Methods

The study was conducted in May–November 2015 in Cipto Mangunkusumo Hospital, Jatinegara Healthcare Center and Matraman Healthcare Center, Jakarta. This is a cross-sectional observational study.

The subjects of this study were suspected tuberculosis patients who went to Puskesmas. Researchers ensure patients meet the study criteria. The inclusion criteria were ≥15 years of age; Patients with pulmonary tuberculosis are on OAT treatment < 1 month or case of pulmonary TB recurrence or pulmonary tuberculosis cases drop out or cases of pulmonary tuberculosis failure treatment OAT or patient suspect

pulmonary tuberculosis with symptoms of cough for more than 2 weeks with 2 other TB symptoms, such as fever, cough blood, night sweats, chest pain, weakness/lethargy, weight loss for no apparent reason, history of contact with smear positive patients or extra pulmonary TB. Patients are willing to follow all the procedures required in the study and sign the informed consent.

The subjects of the study were interviewed and examined by the researcher to complete the medical record (Case Record Form) data upon arrival. Subjects were subjected to clinical symptoms, physical examination and morning sputum were taken for sputum preparation (smear and culture) and thoracic X-ray examination. BTA and culture examination was done in the microbiology department of FKUI, while chest X-ray examination was done in the radiology department of RSCM.

The mean and standard deviations was estimated along with their confidence spans for age to identify the demographic picture (age and sex) of suspected TB patients in the study site. The proportion of sexes was be estimated along with their confidence span, carried out descriptively. The proportion of any sputum examination results for both AFB and culture was estimated to identify the AFB sputum smear (TB smear and culture) of suspected TB patients at the study site.

The validity of radiological scoring is expressed by 2 things, namely the reliability of the read result expressed by the kappa value and the validity value. The kappa value is calculated in reading points in the CRRS, which includes large Opacity (> 1 cm), small Opacity (< 1 cm), Cavity, effusion and consistent with active Tb. Agreements are compared between trained readers and 2 independent readers. The kappa value is used to determine the strength of the agreement of a diagnostic test as suggested by Landis and Koch (1977).

The radiologists filled the CRRS form which contains the scoring based on 4 features: Score 2 is given for Upper lobe large opacity (> 1 cm), cavity in any location, and adenopathy in any location, and score 1 for unilateral pleural effusion. The total number of the score was then categorized using different cut offs (≥ 1, ≥ 2, ≥ 3, and ≥ 4) to evaluate the validity of the method compared with the sputum examination. Two radiologists read the same chest X-ray, and when there was disagreement, a senior radiologist made the final decision. The agreement between the two radiologists was determined using the Cohen's kappa.

3. Results

Of the total 269 suspected tuberculosis screened, 220 (55%) out of the 400 subjects were recruited. Of the 220 subjects, who had been examined AFB sputum, as many as 184 subjects are examined with the culture of M tuberculosis and as many as 210 subjects and who have examined with the chest X-ray. The causes of these facts are as follows: do not meet the study criteria; do not want to go check the chest X-ray to the Radiology department at RSCM; do not want to wait too long/queue at RSCM; still awaiting the latest results of the culture examination; no thoracic photos have been found.

Jatinegara Healthcare Center contributed for the most subjects, followed by Jatinegara Healthcare Center and Cipto Mangunkusumo Hospital subsequently 90 cases (41%), 86 cases (39%) and 44 cases (20%). The number of the recruited subjects at each study site is shown in Figure 1.

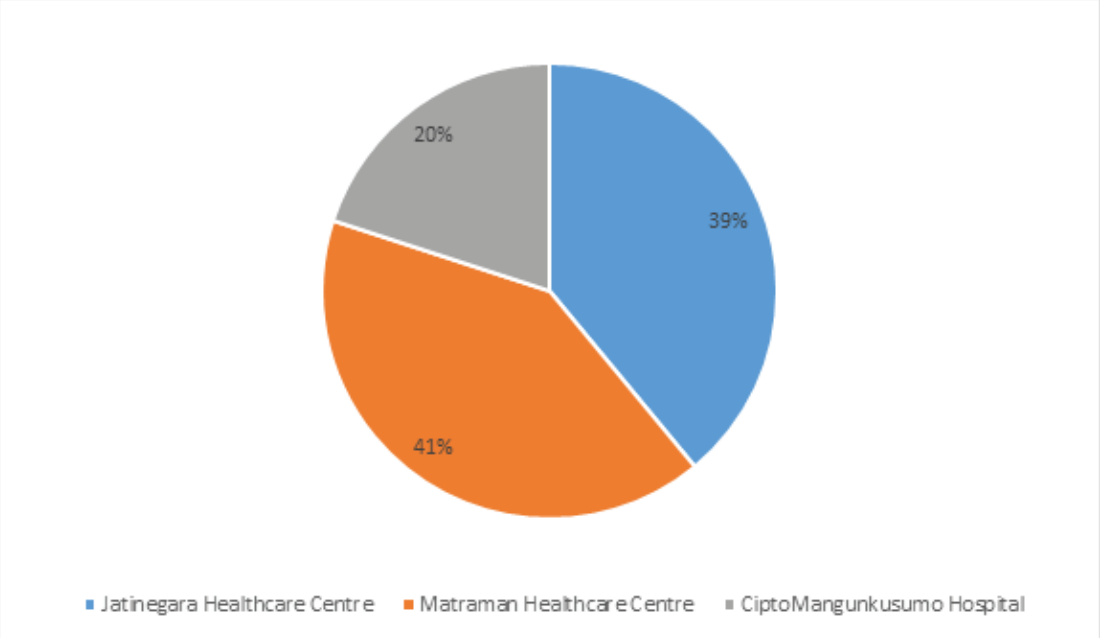

Figure 1: Subjects' distribution based on research location.

3.1. Demographic description (age and sex)

Characteristics of research subjects based on the location of research are shown in Table 1. In general, the subjects of the study was almost equal between men (57%) and women (43%). Subjects recruited had age distribution of 15 to 84 years, with a mean of 41.8 years.

Table 1: Subjects characteristic based on location.

Characteristic	Location			Total N (%)
	PKM Jatinegara n(%)	PKM Matraman n (%)	RSCM n (%)	
Sex				
Male	45 (57)	53 (59.2)	20 (47.6)	118 (56.2)
Female	34 (43)	36 (40.4)	22 (52.4)	92 (43.8)
Age (mean, range)	39.8 (18–84)	39.6 (15–78)	47.9 (21–78)	41.3 (15–84)
Total	**79**	**89**	**42**	**210**

3.2. Clinical symptoms description

Most subjects came to the study site with a major symptom of cough (52%). Other major symptoms are cough with sputum, coughing and dry cough, 52%, 39% and 2%, respectively. In addition to the main symptoms, the subject also comes with some additional symptoms. Additional symptoms are cough with sputum, weight loss, malaise, decreased appetite, fever and night sweats experienced by more than 50% of the study subjects (see Figure 2).

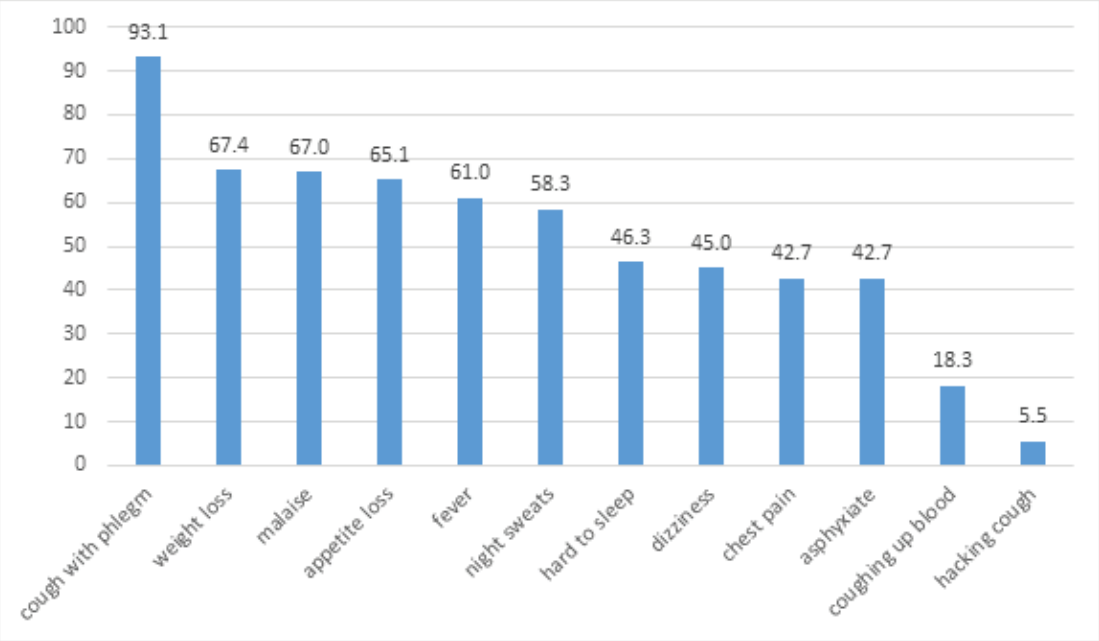

Figure 2: Clinical symptom proportion on the study subjects.

3.3. Routine examination description

Although still awaiting the complete results of routine microscopic examination of BTA and Mycobacterium tuberculosis cultures against the subjects' sputum, the interim

results show that only about 30% of subjects with TB-positive suspected BTA-induced tuberculosis. These positive TB results doubled after the Mycobacterium tuberculosis culture test. Results of positive culture examination 2 times of positive smear examination on the same sample and examined by supranational referral laboratory for tuberculosis.

The Table 2 shows that the most result of active tuberculosis, inactive pulmonary tuberculosis and non-pulmonary tuberculosis based on routine chest X-ray were in Matraman Healthcare Center 30% (63/210), Jatinegara Healthcare Center 2,8% (6/210) and Jatinegara Healthcare Center 17.6% (37/210), respectively.

Table 2: The distribution of subjects based on the results of AFB smear, culture, and routine chest X-ray.

Examination Results	Location			Total N (%)
	PKM Jatinegara n(%)	PKM Matraman n(%)	RSCM n(%)	
AFB Smears				
Positive	12 (17.9)	22 (28.6)	3 (7.5)	37 (20.1)
Negative	55 (82.1)	55 (71.4)	37 (92.5)	147 (79.9)
Total	**67 (100)**	**77 (100)**	**40 (100)**	**184 (100)**
M. TB Culture				
Positive	25 (51.0)	34 (69.4)	8 (32.0)	67 (54.5)
Negative	24 (49.0)	15 (30.6)	17 (68.0)	56 (45.5)
Total	**49 (100)**	**49 (100)**	**25 (100)**	**123 (100)**
Routine Chest X-Ray				
Active TB	36 (45.6)	63 (70.8)	21(50)	120 (57.1)
Old and Inactive TB	6 (7.6)	0	2 (4.8)	8 (3.8)
Non-pulmonary TB	37 (46.8)	26 (29.2)	19 (45.2)	82 (39.0)
Total	**79 (100)**	**89 (100)**	**42 (100)**	**210 (100)**

(n = 210)

A total of 210 chest X-ray images were read using the CRRS method. As shown in Table 3, the most common description of radiological abnormality was large opacity (48.6%). Followed by pleural effusion and cavity, 31.9% and 22.4%, respectively. The rarest radiologic features was lymphadenopathy (5.7%). From this reading, the radiologist concluded that nearly 60% of the total subjects were active TB patients.

Table 3: Distribution of radiologic features on chest X-ray reading with CRRS (*n* = 210).

Radiologic Features	N (%)	
Large Opacity	102	(48.6)
Cavity	47	(22.4)
Effusion	67	(31.9)
Lymphadenopathy	12	(5.7)
Consistent with Active TB	122	(58.1)

3.4. CRRS inter-reader agreement between radiologists

Table 4 showed the agreement (kappa value) between readers 2 and 3, where the highest kappa value was in the big opacity feature (0.84), while the smallest kappa value was in the lymphadenopathy (0.52).

Table 4: Agreement between readers (Kappa) according to radiologic features on CRRS.

Radiologic Feature	Kappa
Large Opacity (> 1 cm)	0.84
Cavity	0.56
Effusion	0.74
Lymphadenopathy	0.52
Consistent with Active TB	0.73

3.5. Validity and accuracy of CRRS

Table 5 showed that the score with cut off ≥1 has the highest accuracy (76%) with Sn = 76.2; Sp = 61.4; PPV = 68.6; NPV = 63.6. The lowest accuracy was found on the score with cut off ≥3 and ≥4, which has the accuracy of 60,8% each.

Table 5: Validity of CRRS in various cut-off (*n* = 210).

Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
≥ 1	76.6	61.4	68.6	63.6	76
≥ 2	67.6	70.2	73.0	64.5	68.8
≥ 3	47.1	77.2	71.1	55.0	60.8
≥ 4	41.2	84.2	75.7	54.5	60.8

Table 6 showed the validity values of each radiologic feature assessed on scores with the CRRS method. The best accuracy shown with a value of nearly 80% was on the large opacity feature. This large opacity feature also shows the greatest sensitivity (87.5%) while other features have the sensitivity of less than 50%. Nevertheless, the value of PPV in the 3 radiological features (large opacities, cavities, lymphadenopathy)

showed the same value of 77.8%. The highest specificity value, more than 90% is shown by lymphadenopathy.

Table 6: Validity of CRRS according to radiologic feature.

Radiologic Feature	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Large Opacity	87.5	68.6	77.8	61.4	79.1
Cavity	43.8	84.3	77.8	54.4	61.7
Effusion	44.1	70.2	65	50	55.7
Lymphadenopathy	13	95.7	77.8	48.9	51.5

Table 7 showed that the validity of the CRRS method compared with routine reading methods of chest X-ray of patients suspected with pulmonary tuberculosis is better. This is probably because the standardized CRRS method makes it easier for readers to draw conclusions.

Table 7: Validity comparation between routine chest X-ray reading method and CRRS in the conclusion of active TB after the culture results were obtained.

Method	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Routine Method	81.8	57.4	70.1	72.1	71
CRRS Method	87.9	64.8	75.3	81.4	78

4. Discussion

In the validation study, the scoring of CRRS method has different result from previous research (Pinto et al.). In the Pinto study, the score with cut off ≥2 showed the best result with NPV of 91.5%. Where the conclusion of the study with the value of NPV 91.5% that in people with negative BTA 91.5% it is not Tb. In other words, these results show that if the score does not show cut off ≥2, the likelihood of people not suffering Tb is 91.5%. While in this study, the score with cut off ≥2 shows the lower NPV (64.5%), meaning that only 64.5% are believed to be true not TB if the smear negative result. This is probably due to differences in the characteristics of the samples in both studies. In Pinto et al. research, the proportion of subjects with positive culture was 29.2%, whereas in this study the number of subjects with positive culture was 63.4%.

The use of CRRS methods should result in a good level of agreement among readers to observe and see abnormalities in X-ray images. As shown in the research of Pinto et al., the largest kappa value is in the large opacity feature (0.7). While the smallest kappa value is found on a small opacity image (0.5). Overall, the TB kappa's active picture value was 0.52. This study compared the agreement between the 2nd and 3rd readers. In accordance with the research of Pinto et al., the largest kappa value was

also obtained on the large opacity picture (0.76). However, the smallest kappa value is found in the pleural effusion feature (0.36), although the percentage of agreement between the two readers is 78.2%. This suggests that using the CRRS method will only increase the value of the agreement by 36% on the pleural effusion image. Overall, however, the conclusion of active TB with CRRS method in this study has a better kappa value (0.75) than the previous study (0.52). Thus, the reader agreement in this study to conclude active TB with the CRRS method is good [16]. The kappa value of the CRRS method is also better when compared with the study using another method against the four features commonly seen in tuberculosis [17].

5. Research Limitation

The number of samples recruited in this study were 220 (55%) subjects and did not meet the sample targets in the study protocol of 400 subjects. This is partly because during the screening process (screening) by the research team, it turns out there are things as follows: subjects does not meet the criteria of research; subjects do not want to go check the ronsen to the Radiology department at RSCM; and subjects did not want to wait too long. Several steps have been taken to obtain the appropriate number of samples, such as: adjusting the research flow so that the subjects are more comfortable, easing the research criteria through the protocol amendment to the Ethics Commission and direct supervision by the central team to solve the constraints faced by the team when doing data collection.

Based on these considerations, the results obtained cannot describe the validity of the actual CRRS method so that further validity testing with larger sample and involving more research sites and more radiologists are needed.

6. Conclusion

The interpretation using CRRS method has good inter-reader agreement. On the other hand, the accuracy of the method for supporting tools in reading chest X-ray for suspected TB patients is lacking. However, we acknowledge that the conclusion may be biased due to the unmet target of number of participants recruited. Further investigation is needed to make definite conclusion.

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References

[1] World Health Organization. (2013). Global tuberculosis report 2013. European Communicable Disease Bulletin.

[2] Badan Perencanaan Pembangunan Nasional. (2012). Laporan Pencapaian Tujuan Pembangunan Milenium di Indonesia 2011.

[3] Badan Litbangkes. (2010). Riset Kesehatan Dasar 2007.

[4] Badan Litbangkes. (2016). Riset Kesehatan Dasar 2013.

[5] Dirjen P2&PL Kementerian Kesehatan RI. (2011). Terobosan Menuju Akses Universal, Strategi Nasional Pengendalian TB di Indonesia 2010-2014. Stop TB, pp. 1–80.

[6] Menteri Kesehatan Republik Indonesia. (2009). Keputusan Menteri Kesehatan Republik Indonesia Nomor 364/Menkes/SK/V/2009.

[7] Sukartini, N. (1998). Perkembangan Diagnostik Tuberkulosis Paru. Indonesian Journal of Clinical Pathology, vol. 5, pp. 7–12.

[8] Ahmad, U. F. (2004). Masalah Tuberkulosis di Indonesia dan Upaya Percepatan Penanggulangan Tuberkulosis, 'Stop TB Sekarang Juga', in Buku Makalah Seminar Tuberkulosis, Dinas Kesehatan Sumatera Utara, PPTI, pp. 52–61.

[9] Amraeni, Y. and Rahmawati. (2013). Sensitifitas dan spesifisitas screening tuberkulosisi di Rumah Sakit Bahtera Mas Tahun 2013. STIKES Mandala Waluya.

[10] Kumar, B. D., Bhargava, S. K., Agrawal, C. S., et al. (2005). Chest radiographs and their reliability in the diagnosis of tuberculosis. Journal of Nepal Medical Association, vol. 44, pp. 138–142.

[11] Den Boon, S., et al. (2005). Development and evaluation of a new chest radiograph reading and recording system for epidemiological surveys of tuberculosis and lung

disease. International Journal of Tuberculosis and Lung Disease, vol. 9, no. 10, pp. 1088–1096.

[12] Dawson, R., et al. (2010). Chest radiograph reading and recording system: Evaluation for tuberculosis screening in patients with advanced HIV. International Journal of Tuberculosis and Lung Disease, vol. 14, no. 1, pp. 52–58.

[13] Pinto, L. M., et al. (2013). Development of a simple reliable radiographic scoring system to aid the diagnosis of pulmonary tuberculosis. PLoS One, vol. 8, no. 1.

[14] Kementerian Kesehatan Republik Indonesia. (2014). Profil Kesehatan Indonesia 2013. Profil Kesehatan Indonesia 2013. Retrieved from http://www.depkes.go.id/resources/download/pusdatin/profil-kesehatan-indonesia/profil-kesehatan-indonesia-2013.pdf

[15] Badan Penelitian dan Pengembangan Kesehatan Kementerian Republik Indonesia. (2011). Laporan Akhir Riset Fasilitas Kesehatan 2011. Laporan Akhir Riset Fasilitas Kesehatan 2011.

[16] Viera, A. J. and Garrett, J. M. (2005). Understanding interobserver agreement: The kappa statistic. Family Medicine, vol. 37, no. 5, pp. 360–363.

[17] Grozdanovic, Z., et al. (2015). A novel reading scheme for assessing the extent of radiographic abnormalities and its association with disease severity in sputum smear-positive tuberculosis: An observational study in Hyderabad/India. PloS One.