A New Surveillance Model of Tuberculosis Transmission Control Based on Geographic Information System in the Primary Health Care

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ABSTRACT

Background: Tuberculosis can cause a substantial challenge against public health, especially in the developing countries which have low level of socio-economic condition that does not support the control over tuberculosis transmission and infection. Objective: To find a new surveillance model of tuberculosis transmission control based on geographic information system data in improving the tuberculosis transmission control and treatment outcome. Methods: Effectiveness test of the self-monitoring of calendar documentation on the tuberculosis transmission control and outcome treatment with quasi-experimental post-test only with control group design. The analytical unit consisted of 96 tuberculosis cases as the self-monitoring group of calendar documentation (intervention) and 87 tuberculosis cases as the control group sourced of two different primary health care. Results: The self-monitoring intervention of calendar documentation increased the average treatment effect on medicines intake control 0.11 (95% CI: 0.01-0.21), environment control 0.32 (95% CI: 0.19-0.46), droplets nuclei control 0.49 (95% CI: 0.36-0.61), cured 0.22 (95% CI: 0.09-0.36), completed 0.18 (95% CI: 0.09-0.26), drop out 0.09 (95% CI: 0.01-0.16), and failure of treatment 0.18 (95% CI: 0.09-0.26) of the control group (baseline). Conclusion: The final result of this research found a new surveillance model of tuberculosis transmission control in google earth mapping application based on Geographic Information system. Keywords: Self-Monitoring, Calendar Documentation, Tuberculosis Transmission Control, GIS. Primary Health Care.

1. BACKGROUND

Tuberculosis is a disease which is caused by mycobacterium tuberculosis. It is a global health problem which has infected about eight million people per year throughout the world (1) It also causes the death of 1.5-2 million people. Besides causing death, it can also cause the incidence of resistant tuberculosis, the decrease in family income, the loss of work days, poverty, and malnutrition (2). Tuberculosis can cause a substantial challenge against public health, especially in the developing countries which have low level of socio-economic condition that does not support the control over tuberculosis transmission and infection (1, 2).

The high prevalence of non-adherence to taking medicines, negative control of room air circulation, and un-controlling to spread of droplet nuclei are the components which cause the high incidence of tuberculosis transmission (6, 7). The result of research in 2020 on 200 tuberculosis patients in Deli Serdang Regency found that the patients of non-adherent to medicines intake of 21.5%, non-adherent to wearing masks of 66.5%, non-adherent to using handkerchiefs of 64.5%, negative control of the air circulation of 79.5%, and threw away their sputum haphazardly of 77%.6 Even though the success rate of tuberculosis treatment was acknowledged increasing continuously and the data indicate that adherence to taking medicines reaches 85.1% in Indonesia in 2020 however, the control of tuberculosis transmission was still high...
in the populations (7).

Up to the present time, many literature reviews on behavior intervention which have recommended intervention of the self-monitoring of calendar documentation (SM-CD) administratively toward the control on medicine intake, environment, and droplet nuclei (8-11). Even though substantial evidence about the effectiveness of transmission control approach through intervention of the SM-CD for decreasing the burden of transmission from person to person concerning tuberculosis is not stated specifically, however in the intervention of chronic diseases, some evidence has indicated the effect of SM-CD on the adherence to taking medicines (11-15). Based on the explanation above, it can be said that intervention of the SM-CD hypothesized to be able to increase the control on tuberculosis transmission and the treatment outcome in the directly observed treatment, short-course (DOTS) program. Jorgensen, in his research, even points out that intervention of the SM-CD yields routine data which are useful for a study and analysis on risky behavior and recommended the development of behavioral surveillance in the future (15). Based on the hypothesis, this research developed operational definition of the research as followed.

SM-CD is a person’s capability of connecting a new behavior for a moment or condition and recording behavior in the action into calendar documentation.

Medicines intake control is a controlled behavior (adherence) in taking anti-tuberculosis medicines according to the direction of directly observed treatment, short-course (DOTS) program officer in order to prevent the incidence of transmission from one tuberculosis patient to the vulnerable population.

Environment control is controlled efforts toward behavior of opening windows of the room at least 60 minutes in the morning just before noon in order to keep air circulation of the room. It is also concerned with throwing sputum into a closed receptacle according to the suggestion of the primary health care (PHC) officers of the DOTS program in order to prevent tuberculosis transmission from a tuberculosis patient to vulnerable population.

Droplet nuclei control is a controlled behavior toward the use of masks at home and outside the house, the use of handkerchiefs when someone coughs and sneezes according to the suggestion of the PHC officer of DOTS program in order to make tuberculosis not spread its aerosol droplet to vulnerable population.

Reproduction number is the rate which states a tuberculosis patient’s probabilities to transmit mycobacterium tuberculosis to vulnerable people caused by the weak of control on medication, environment, and droplet nuclei.

Treatment outcome is the explicit meaning of tuberculosis medication intervention program which is stated in recovery, completeness, drop out, and case failure.

The surveillance model implemented in the control of tuberculosis in Deli Serdang Regency is a conventional surveillance model. It is oriented towards baseline evaluation, response alerts, and follow-up evaluations that in focusing on the core target of the DOTS program at the Primary Health Care (PHC). DOTS surveillance system has its weaknesses especially on the inability to detect risky behavior of the transmission of tuberculosis patients related on the medicines intake control, environment control, and droplet nuclei control. Another weakness is the inability to detect the natural history of active tuberculosis transmission and multiple drug resistance (MDR), the inability to detect social and environmental conditions which influence tuberculosis transmission, and the inability to detect the case based on coordinating point with online access. These weaknesses have caused the increase in the basic reproductive number (R0) of 1.3 (R0 > 1) cases per household. R0 of 1.3 indicates that even though the success rate increases, tuberculosis transmission in the treatment process from patients to vulnerable populations has also increased. This indicates that it is very important or significant to develop intervention against tuberculosis transmission.

The development of surveillance system as a monitoring device combined with Google earth application has been proven to improve the performance of tuberculosis control, especially in controlling the transmission of tuberculosis cases in the population (16). Use of geographic information system (GIS) analysis that is combined with SM-CD in the Google earth as a mapping model can become an effective method to identify tuberculosis transmission (17, 18).

Up to these days, as far as we know, no research has found a new surveillance model of tuberculosis transmission control based on GIS data. SM-CD intervention is implemented in the PHC based on DOTS program (9). By comparing the tuberculosis transmission control and treatment outcome in the SM-CD intervention group with the control group, the data of reproductive number (R0) and GIS can be developed and explored into Google earth application.

2. OBJECTIVE
The aim of this study was: 1) to analysis the effect of SM-CD on the control of tuberculosis transmission and treatment outcomes, and 2) to find a new surveillance model of tuberculosis transmission control based on GIS in improving the tuberculosis transmission control and treatment outcome

3. MATERIAL AND METHODS
Design
The research used quasi-experiment method with post-test only with control group design which was aimed to test the effectiveness of the tuberculosis transmission control with the ratio of intervention group: control group was 1:1 serial.

Tuberculosis Patient Recruitment
Tuberculosis patients were recruited from two PHC (Patumak and Deli Tua) for the intervention group (100 participants; 96 units of analysis) and two PHC (Biru-Biru and Talun Kenas) for the control group (100 participants; 87 units of analysis) (diagram 1). The four PHC provided DOTS service with the criteria of management and the same resource qualification. The recruitment of patients was carried out when the patient were diagnosed with new tuberculosis, both pulmonary tuberculosis bacteriological (PTB+) and clinical (PTB-) from the result of the confirmation of PHC laboratory, clinic, or hospital. The confirmed tuberculosis patients were screened based on the inclusion criteria: Pulmonary tuberculosis, new tuberculosis cases, age > 20 years, patient monitored by cadre, DOTS program patients, fixed dosage combination (FDC), and having bedroom window(s).
exclusion criteria were MDR tuberculosis, HIV/AIDS tuberculosis, Diabetes Mellitus tuberculosis, Gestational tuberculosis, and COVID-19 tuberculosis. The recruitment of participants based on consecutive technique for five months from March to August, 2021.

**Training**

The DOTS program officers in the two SM-CD intervention locations were trained to fill out calendar documentation in one meeting of one hour. The selected two PHC in the SM-CD intervention group found the average of 30 new tuberculosis cases per month, either they were diagnosed by the PHC laboratory or clinical doctors or they were referred by a hospital.

**Intervention**

All tuberculosis patients in the SM-CD intervention groups received explanation about the procedure of filling out calendar documentation and the instruction of patients’ participation and responsibility during the intervention program by the PHC tuberculosis program officer (figure 4). Duration of the whole intervention was 11 month from March 2021 to February 2022. The intervention of calendar documentation of the medicines intake control was conducted for six months (follow-up 1-6 treatment), the intervention of environmental control and droplet nuclei was done for two months (follow-up 1-2 medication). During the intervention, a tuberculosis patient received six sheets of calendar documentation (figure 4) and six ballpoints which were distributed in each follow-up treatment, one box of masks containing of 50 pieces and two handkerchiefs which were given in the follow-up 1-2. The calendar documentation was filled out by patients at home by giving checklists in each activity of medicines intake control, opening windows every morning, throwing sputum into covered receptacles, using masks, and closing mouths with handkerchiefs when they were coughing and sneezing. Calendar documentation was distributed to tuberculosis patients when they took their medicines at the beginning of treatment follow-up and returned when took the medicine at the next follow-up.

**Bias Control**

Calendar documentation has fulfilled the validity content by consulting three pulmonary specialists and four senior staffs of DOTS program. External validity for treatment cards of DOTS tuberculosis program and pilot study for 20 patients of DOTS tuberculosis program with the very strong agreement value (Kappa = 0.7-1) (figure 5). Keeping balance between intervention group and control group was done by 1) distributing self-monitoring modules of tuberculosis documentation, masks, and handkerchiefs to the SM-CD group and the control group, 2) performing restriction with inclusion and exclusion criteria, and 3) making adjustment in the data analysis. The validity of information was done by 1) instruction of participation and responsibility, instruction of filling out calendar documentation, reminding of WhatsApp group, and recalling information about 30 SM-CD intervention patients with very strong agreement values (Kappa=0.7-1) (figure 6,7).

**Data Collection**

The data on the tuberculosis patients’ characteristics were gathered when they were registered and confirmed with the patient tuberculosis cards at the PHC. The data of global positioning system (GPS) were gathered at their home in the follow-up 1 of treatment in the working area of the PHC of intervention group. The data on the control of patients’ tuberculosis transmission were gathered through questionnaire list of adherence which was confirmed from calendar documentation (intervention group) and from tuberculosis cards (control group). The list of patients’ adherence consisted of one question on medicines intake control, two questions on environment control, and two questions on droplet nuclei control with the answering category of each question: 1 (controlled), 2 (uncontrolled). Questions on environment control and droplet nuclei were included in the variables of environment and droplet nuclei controls with the criteria as follows: if the two answers were controlled, they were given category 1 (controlled) and if one of the answers was not controlled or even both of them were uncontrolled, they were given category 2 (uncontrolled).

**Statistical analysis**

Data was entered, checked, cleaned and analysed using STATA. Bivariate analysis to determine the effect of SM-DK intervention on control of transmission and treatment outcome was performed by treatment effect binary outcome regression adjustment with Average Treatment Effect (ATE) 95% confidence interval.

**New Surveillance Model Design**

The placement of tuberculosis case dot map from the GIS data in Google earth application based on the basic reproductive number (R0) is weighed with the index of tuberculosis transmission in household (Ir). R0 was determined with the following formula Anderson (19)

\[ R_0 = \beta.c.(Ir.D) \]

in which R0, basic reproductive number; \( \beta \), the probability of risk factor of tuberculosis transmission; \( c \), serial time; \( Ir \), the index of transmission in household; and \( D \), the number of contacts between household members. \( I_if \cap (\beta_i) = 1, p \) (medicines intake control) + p (environment control) + p (droplet nuclei control) = 1. The risks of medicines intake control, environment control, and droplet nuclei control conversed from the risk of tuberculosis transmission based on Saunders reference.20 The dot map of tuberculosis transmission risk in Google earth was determined with blue dots (drop-out patients), red dots R0 > 2 (high risk of transmission), pink dots R0 1-2 (moderate risk of transmission), yellow dots R0 = 1 (low risk of transmission), and green dots R0 < 1 (very low risk of transmission)

4. RESULTS

The effectiveness of SM-CD as a data collection tool on the transmission control and treatment outcome tuberculosis

In the process of sampling, it was obtained that the inclusion of patients who could be assigned as participants in this study. The number of participants included in the analysis was 188 patients (response rate = 91.5%), drop-out of 8.5% participants were consisted of 2.0% participants from the intervention groups and 6.5% participants from the control groups (diagram 1).

The average age of the tuberculosis patients was 43.3 years old with a standard deviation of 15.2. Most of tuberculosis patients were 56.3% males, 86.3% were married and 82% the education length were ≤ 9 years of schooling. In terms of
association with tuberculosis transmission, most of the tuberculosis patients of 80.9% had no history of BCG immunization, tuberculosis patients’ status was 60.1% PTB+, and the mean of household contacts was 3.9. Occupation and family income of the tuberculosis patients were mostly low in physical activity of 69.9% and family income was 71.6% < IDR.3,000,000 per month.

The results of multivariate analysis after adjustment found that the ATE of SM-CD intervention increased in the controlled behavior of medicines intake 0.11 (95% CI: 0.01-0.21), controlled environment 0.32 (95% CI: 0.19-0.46), and controlled droplet nuclei 0.49 (95% CI: 0.36-0.61) of the mean baseline (control group) with the potential outcome mean (POmean) of 0.80, 0.32, and 0.34 consecutively. The ATE of SM-CD intervention also increased in cure 0.22 (95% CI: 0.09-0.36), completed 0.18 (95% CI: 0.09-0.26), drop-out 0.09 (95% CI: 0.01-0.16), case failure 0.18 (95% CI: 0.09-0.26), and reproductive rate -0.11 (-0.20-(-0.02) from the mean baseline (control group) with POmean of 0.68, 0.78, 0.87, 0.78, and 0.79 consecutively (Table 1).

The effectiveness of the new surveillance model on the control of transmission and treatment tuberculosis

The use of a new surveillance model of tuberculosis transmission control in detecting the risk behavioral of the tuberculosis transmissions is a new approach that can be applied in PHC as a surveillance tool for DOTS programs (Figure 1). This figure shows the advances of tuberculosis transmission control from 1-6 follow-up of treatment. The progress in control of transmission shows that the very low risk and tends to increase from follow-up 1 (48%) to follow-up 6 (54%), while the low risk also increases from follow-up 1 (20%) to follow-up 6 (24%). Tuberculosis transmission with moderate

<table>
<thead>
<tr>
<th>TB transmission control</th>
<th>ATE (95% CI)</th>
<th>POmean (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM-CD vs medicines intake control</td>
<td>0.11 (0.01-0.21)*</td>
<td>0.80 (0.72-0.88)**</td>
</tr>
<tr>
<td>SM-CD vs environment control</td>
<td>0.32 (0.19-0.36)**</td>
<td>0.32 (0.22-0.42)**</td>
</tr>
<tr>
<td>SM-CD vs control of droplet nuclei</td>
<td>0.49 (0.36-0.61)**</td>
<td>0.34 (0.24-0.44)**</td>
</tr>
</tbody>
</table>

Table 1. Results of Treatment Effect Analysis of the SM-CD on Tuberculosis Transmission Control and Treatment Outcomes after Adjustment. * p < 0.05; ** p < 0.01. Note: SM-CD, self-monitoring calendar documentation; TB, tuberculosis; ATE, average treatment Effect; POmean, potential outcome mean; CI, confidence interval. a Effect of SM-CD group (n = 96) vs control group (n = 83) controlled by age, history of immunization, TB status, and household contact. b Effect of SM-CD (n = 100) vs control group (n = 100) controlled by age, history of immunization, TB status, and household contact. c Effect of SM-CD group (n = 47) vs control group (n = 70) controlled by age, history of immunization, TB status, and household contact

Figure 1. Advance of reducing the risk of tuberculosis transmission follow-up 1-6 treatment using the google earth application at the Patumbak Health Center in 2021-2022

Figure 2. Mapping of tuberculosis cases in the work area of the Patumbak Primary Health Care in follow-up 1 and 6 treatments on application of Google earth in 2021
risk tended to decrease from follow-up 1 (30%) to follow-up 6 (18%), while for high-risk and drop-out were more constant throughout follow-up tuberculosis treatment.

The role of SM-CD in improving treatment control and treatment outcomes shows the effectiveness of calendar documentation as a data collection instrument. Thus the surveillance model file of Google earth mapping at Patumbak PHC can be created in the TB_project_patumbak.kmz file based on the GIS data and patient profile data which are surveyed directly from the TB patient’s home. The mapping of the control of tuberculosis transmission based on geographic information system data for follow-up 1, 2, 6 and end of treatment in the Google Earth application in the work area of the Patumbak PHC showing in Figure 2. It was mappings by using map dots put on coordinate point of the longitude and latitude at the patients’ houses. The green and yellow dots show that transmission does not require special intervention, while pink and red indicated that transmission had to be controlled with quick response (Figure 2)

Follow-up 1 of treatment showed that In the TB_project_patumbak.kmz file, TB surveillance officers entered data on tuberculosis transmission control (adherent and non-adherent) which were collected from calendar documentation in the first month of treatment. The results of online monitoring at follow-up 1 treatment showed that 30% of patients with moderate risk of transmission (pink) should receive health promotion, 68% (green and yellow) with low risk, and 2% drop-out. Follow-up 2 of treatments showed that the data were re-entered at 2 months of treatment from calendar documentation. The results of online monitoring by PHC officers showed that 36% of patients (pink and red) should receive health promotion, 62% of low risk of transmission (green and yellow), and 2% of drop-out (blue). Illustration of follow-up 3-5 is the same as follow-up 2.

Follow-up 6 of treatments showed that the transmission control data were re-entered at 6 months of treatment from calendar documentation. The results of online monitoring by PHC officers showed 18% of moderate risk patients (pink), 2% of high risk patients (red), 74% of low risk patients (green and yellow) and 4% drop-out (blue). The TB_project_patumbak.kmz file is saved. The end of treatment: is a mapping file that is changed from the TB_project_
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CALANDAR DOCUMENTATION OF TUBERCULOSIS TRANSMISSION CONTROL

<table>
<thead>
<tr>
<th>Patient name</th>
<th>Treatment process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration No.</td>
<td>Start Date</td>
</tr>
<tr>
<td>Period / Month</td>
<td></td>
</tr>
</tbody>
</table>

**ACTIVITY**

**TREATMENT CONTROL**

- Taking medicine (1)

**ENVIRONMENTAL CONTROL**

- Opening the Bedroom Window immediately after waking up to promote air circulation (2)
- Dumpling sputum in a closed container (3)

**DROPLET NUCLEI CONTROL**

- Use a mask when leaving the room and traveling outside the house (4)
- Covering mouth with handkerchief when coughing and sneezing (5)

Calendar documentation is marked (i) every day after doing activities: taking medicine (1). The environmental control entry consists of two available fields no (2) & (3). Filling in the breath control consists of two lines of entries no. (4) & (5). Try to fill out the calendar documentation at night before going to bed and put the calendar documentation in a place that is easily accessible from the bed. Calendar documentation is received at the time of taking medication for the first (25 days) period and returned at the end of the second treatment period (after taking medication for the third period). Caution: If you don’t take medicine, don’t open your bedroom window, don’t dispose of your sputum in a closed container, don’t wear a mask, and don’t cover your mouth when you cough and sneeze, you don’t need to fill in the CALENDAR DOCUMENTATION on the date you don’t do these activities.

Figure 4. Calendar documentation of tuberculosis patient. Note: p= Kappa statistics of calendar documentation of the question items 1-9, p1= baseline, unattractive colour, p2= baseline, complicated picture, p3-p7= baseline, difficult to fill in, p8= baseline, difficult to understand instructions; p9=baseline, image is not bright, Kappa value (0.5-0.75 (good agreement), Kappa >0.75-1 (strong agreement))

patumbak.kmz file to TB_project_outcome_patumbak.kmz within one year after the treatment outcome data from the calendar documentation is entered into the map. Mapping of tuberculosis cases in the treatment outcome map for 50 tuberculosis cases showed 78% of patients were complete (grey), 18% cured (white), and 4% drop-out (blue). This file is saved for overlay analysis of the history of tuberculosis transmission in the population in the following years.

5. DISCUSSION

The effect of SM-CD on the transmission tuberculosis control emphasized that calendar documentation as self-monitoring device is a significant new finding as the instrument of data collection in a surveillance model of Google earth mapping (15). The objective of Google earth mapping was to describe the distribution of tuberculosis cases and the most important is as a surveillance tool of tuberculosis transmission control can display and monitor tuberculosis cases visually and online (21). Surveillance system using Google earth mapping is a monitoring system that is easy to update, maintain, inexpensive and user-friendly (21, 22).

A map can describe the position of patients geographically. Mapping tuberculosis cases in Google earth application can do overlay and query analysis (21-24). Query can provide

Figure 5. The results of Kappa’s statistical analysis on the feasibility of using calendar documentation as a data collection instrument (N=20 patient of tuberculosis). Note: F: Treatment follow-up, Kappa statistical value 0.5-0.75 (good agreement), Kappa >0.75-1 (strong agreement)

Figure 6. Results of recalling calendar documentation on behaviour of taking medicine at the Patumbak and Deli Tua Public Health Centers in 2021 (N=30 tuberculosis patients). Note: F: Treatment follow-up, Kappa statistical value 0.5-0.75 (good agreement), Kappa >0.75-1 (strong agreement)
important information for tuberculosis officers at a PHC about the data of tuberculosis patients. The case number 42 (red colour) of indicated that the case had high risk of transmitting tuberculosis (Figure 3).

Query was then done to complete this information. From the result of the query analysis, it was found that the case in the name of Jhonson Simarmata, 45 years old, status tuberculosis = PTB+, no history of immunization, household contact = 6, medicine control= adherence, environment control= adherence, and droplet nuclei control= adherence. The description of tuberculosis case like this indicates that the control on tuberculosis transmission in a patient was adherence, but it shows red colour in the map. From this fact, tuberculosis personnel at the PHC can conclude that intervention which has to be done is household intervention (the number of family members who have the risk or need isolation). If the case is about disobedience in taking medicines and presence in the red zone in the map, intervention has to be carried out to increase patients’ adherence to take medicines (23, 25).

Household contact, density of household members, distance between cases, distance from a case to PHC, and home environment as shown in Figure 4 is a critical thing which can be analysed in tuberculosis transmission (5, 26). The distance from a case to PHC is closely related to the behaviour in taking medicines, transportation facilities and road condition (16, 21). Distance between cases epidemiologically can take into consideration the possibility of tuberculosis transmission to household members or neighbours. Mapping Google earth can specifically describe the areas which have high risk in the safe of a polygon such as flood areas and humidity, densely populated settlements, slumps, and landfill areas (27).

The analysis on tuberculosis natural history (the end of treatment) is important to be done to determine a tuberculosis transmission model in population, especially in detecting MDR TB cases as shown in Figure 2. Observation of MDR TB cases through overlay analysis by overlaying the mapping of the final results of the previous 5-10 years program in one layer. This analysis can settle the gap of dosage errors since very often the staff of DOTS program gave the first-line dosage of medicines in tuberculosis cases. However, in 3-4 months or even 6 months, tuberculosis patients do not undergo changes in the symptoms. After they are examined, it is found that they are diagnosed with MDR tuberculosis. If this case occurs, they have to repeat the treatment of MDR tuberculosis with the new dosages (28).

6. CONCLUSION

The finding of a new surveillance model using Google earth mapping with calendar documentation as the instrument of data collection plays its role in increasing the behavior of transmission control and treatment outcome, and as a monitoring and detecting devices for the risk of tuberculosis transmission at a working area of the PHC. It is recommended that the new surveillance model can be widely replicated in primary health care as a first-line tuberculosis control platform to achieve tuberculosis elimination by 2035.

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