Spatio-Temporal Dynamics of Tuberculosis Clusters in Indonesia

Dyah Wulan Sumekar Rengganis Wardani, Endro Prasetyo Wahono

Department of Public Health, Faculty of Medicine, University of Lampung, Department of Civil Engineering, Faculty of Engineering, University of Lampung, Bandar Lampung, Indonesia

Abstract

Context: Stratification of social determinants leads to clustering of low socioeconomic communities, which then leads to spatio-temporal tuberculosis (TB) clusters. While previous studies have investigated spatio-temporal TB clusters, few have reported on the dynamics of them and the characteristics of social determinants. Aims: To investigate the spatio-temporal dynamics of TB clusters in Bandar Lampung, Indonesia, from 2015 to 2016, and to identify the characteristics of population density and percentage of poverty of the clusters. Settings and Design: A cross-sectional study was performed to analyze the spatio-temporal dynamics of TB clusters. The sample consisted of 705 TB patients (2015) and 1134 TB patients (2016), registered in 30 community health centers in Bandar Lampung, Indonesia. Subjects and Methods: Geographical coordinates of the TB patients’ residence were collected using Geographical Positioning System. Secondary data, consisting of population density and the percentage of poverty, were obtained from the subdistrict office in the region under investigation. Statistical Analysis: Data were analyzed with space–time permutation model using SaTScan software. Results: Spatio-temporal dynamics of TB clusters were found in 2015 and 2016, including the number of significant clusters, TB cases within the clusters, as well as locations and sizes of the clusters. All the clusters were found to have similar social determinant characteristics: medium–high population density and low–medium percentage of poverty. Conclusions: TB control programs in countries with a high TB burden and low social determinants should consider the spatio-temporal dynamics of the TB cluster and its social determinant characteristics for a better TB’s intervention.

Keywords: Cluster, dynamics, spatio-temporal, tuberculosis

Introduction

Tuberculosis (TB) is strongly correlated with low social determinants, such as education, occupation, income, as well as social class. Previous reviews have stated that low social determinants directly, or through risk factors (i.e., poor housing conditions, poor food security, and poor healthcare access), influence the risk of contracting TB. Research on TB and social determinants has also reported similar findings, including studies conducted in Indonesia, which found that low social determinants, poor housing conditions, and poor food security were correlated with TB transmission, TB incidence, and sputum conversion delay. These findings reinforce the need to provide social protection, alleviate poverty, and address other determinants of TB under the policy and system of a TB control program.

Furthermore, stratification of social determinants leads to clustering of low social determinant communities. Due to their condition, TB patients tend to be clustered in low socioeconomic communities. Clustering refers to the significant aggregation of disease events based on spatial and/or temporal parameters (space–time). This includes information, such as cluster location, cluster size, and the number of disease cases inside the cluster. Studies conducted in Vitoria, Brazil; Antananarivo, Madagascar; Bandar Lampung, Indonesia; and Hermosillo, Mexico, have reported that clustered TB incidence is located in low social determinant areas.

Significant TB clusters based on time and location (spatio-temporal TB) provide information about where vulnerable people live; they also provide an indication...
of the characteristics of those communities. The information is very useful in supporting a TB control program, especially for focusing on interventions to address the determinants and the intervention area. Therefore, the information should be provided continuously to identify whether there are dynamics associated with the location, size, and number of cases in the cluster. However, only a few studies have investigated the dynamics of spatio-temporal TB clusters.

The present study investigated the dynamics of spatio-temporal TB clusters in Bandar Lampung, Indonesia, in 2015 and 2016, and it identified the characteristics of the social determinants of the clusters. In this research, the social determinants were represented by the indicators of population density and the percentage of poverty in the studied clusters.

**Subjects and Methods**

A cross-sectional study was performed to investigate the dynamics of the spatio-temporal TB clusters in Bandar Lampung in 2015 and 2016. The study population included all smear-positive TB patients who were registered at all 30 community health centers that had implemented a directly observed treatment short-course strategy during the study. The sample included all study population with an accurate address, who had not moved to another place and who were still alive.

Variables in this study consisted of the geographical coordinates of the residences of the sample and the social determinant indicators (subdistrict population density and percentage of poverty). The population density is the subdistrict total population divided by the area in kilometers square (km²) (low density: <2500 persons/km², middle density: 2501–7500 persons/km², and high density: >7501 person/km²). In the present study, the percentage of poverty in the subdistrict poverty was classified into three levels, based on the Human Poverty Index of the United Nations Development Program: low (<5%), middle (5%–10%), and high (10%). The social determinant data were obtained from the secondary data for each subdistrict population. The geographical coordinates of the study sample’s residences were obtained using Geographical Positioning System tools. They were then analyzed with the space-time permutation model using the SaTScan™ software developed by Martin Kulldorff together with Information Management Services Inc/ to identify the spatio-temporal TB cluster. In the present study, the spatio-temporal cluster time aggregation was 3 months. This time aggregation was based on the consideration that, after 2 months of treatment, smear-positive TB patients would have sputum conversion, and there was a 14-day delay before new TB patients in Indonesia would receive treatment. The spatial-temporal clusters were then overlaid with the subdistrict population density and percentage of poverty data. The results were visualized using the Geographical Information System program.

This research received ethical approval from the Faculty of Medicine, University of Lampung. The respondents also provided informed consent; their participation was voluntary.

**Results**

In 2015, the eligible samples consisted of 705 smear-positive TB patients. In 2016, the eligible samples consisted of 1134 smear-positive TB patients. The analysis results showed that, in 2015, there were three TB spatio-temporal clusters. The first (the most likely) cluster was in the subdistricts of Tanjung Karang Timur, Way Halim, Labuhan Ratu, and Sukarame (coordinate center at latitude −5.38289, longitude 105.281088 with a 4.40 km radius; \(P = 0.000021\)). There were 94 TB cases in that cluster. The second cluster (secondary cluster 2) was located in the subdistricts of Teluk Betung and Bumi Waras (coordinate center at latitude −5.445093, longitude 105.272562 with a 2.21 km radius; \(P = 0.0021\)). There were 184 TB cases in that cluster. The third cluster (secondary cluster 3) was located in the Teluk Betung Utara subdistrict (coordinate center at latitude −5.425175, longitude 105.276625 with a 0.26 km radius; \(P = 0.974\)). There were seven TB cases in that cluster.

In 2016, there were also three TB spatio-temporal clusters. The first (most likely) cluster was located in Kemiling subdistrict (coordinate center at latitude −5.391621, longitude 105.264814 with a 1.98 km radius; \(P = 0.0025\)). There were 15 TB cases in that district. The second cluster (secondary cluster 2) was located in the Tanjung Karang Timur subdistrict (coordinate center at latitude −5.408078, longitude 105.264814 with a 0.50 km radius; \(P = 0.286\)). There were 13 TB cases in that cluster. The third cluster (secondary cluster 3) was located in the Kedaton, Way Halim, Rajabasa, and Labuhan Ratu subdistricts (coordinate center at latitude −5.371937, longitude 105.251907 with a 3.72 km radius; \(P = 0.450\)). There were 166 TB cases in that cluster. The only significant spatio-temporal cluster was the first (most likely) cluster. All three clusters are shown in Figure 1. A brief overview of the SaTScan analysis results is presented in Table 1.

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The spatio-temporal TB clusters in 2015 and 2016 were then overlaid with the population density in 2015 and 2016, as illustrated in Figures 3 and 4. As shown in Figure 3, in 2015, the first (most likely) spatio-temporal TB cluster was located in the Tanjung Karang Timur, Way Halim, Labuhan Ratu, and Sukarame subdistricts, with a high and middle population density. In 2015, the secondary cluster was located in high population density areas: the Teluk Betung Selatan and Bumi Waras subdistricts. However, as seen in Figure 4, in 2016, the first (most likely) spatio-temporal TB cluster was located in the Kemiling subdistrict, with a middle population density.

Regarding poverty classification, the first (most likely) spatio-temporal TB cluster in 2015 was located in the Tanjung Karang Timur, Way Halim, Labuhan Ratu, and Sukarame subdistricts; the percentage of poverty in those subdistricts was low and middle. In 2015, the secondary cluster 2 was located in the Teluk Betung Selatan and Bumi Waras subdistricts,
with a middle percentage of poverty. In 2016, the most likely spatio-temporal TB cluster was located in Kemiling District, with a low percentage of poverty.

**Discussion**

The results demonstrate that the spatio-temporal dynamics in the TB clusters in 2015 and 2016 included the number of significant clusters, the number of TB cases in the clusters, the cluster locations, and the cluster sizes. The dynamics of the significant number of TB clusters and the number of TB cases in the clusters were demonstrated by the differences in the number of TB clusters and the number of TB cases in the clusters for 2015 and 2016. In 2015, there were two significant clusters: one first (most likely) cluster and one secondary cluster 2. In 2016, there was only one cluster, the first (most likely) cluster. Moreover, in 2015, two significant clusters were residence to 278 of the 705 TB patients. In 2016, one significant TB cluster had 15 of 1143 TB patients. Thus, the clusters in 2015 were residence to most of TB patients in that year. This result is in accordance with the findings reported in a research study conducted in China, which also showed that significant clusters tend to develop in areas with a high TB prevalence and notification rate.[20,21]

In the present study, significant clusters developed in the subdistricts with a high TB notification rate. In 2015, the first (most likely) cluster was found in the Labuhan Ratu, Kedaton, Way Halim, and Sukarame subdistricts. The total notification rate in those subdistricts in 2015 was 143/100,000 people. In 2015, the secondary cluster 2 was found in the Teluk Betung Selatan and Bumi Waras subdistricts; in that year, the total notification rate in those subdistricts was 173/100,000 people. In 2016, although the cluster only consisted of a few TB patients, the cases were similar in terms of the time and location of the TB diagnosis. This finding is also supported by the large TB notification rate in the cluster area. In 2016, the notification rate in the Kemiling subdistrict was 145/100,000 people. Moreover, in the present study, the notification rate in the cluster areas was higher than the notification rate in the non-TB-clustered areas.

The results demonstrate that TB cluster dynamics also include shifting cluster locations. As previously mentioned, the locations of the TB clusters in 2015 included the Labuhan Ratu, Kedaton, Way Halim, Sukarame, Teluk Betung Selatan, and Bumi Waras subdistricts. In 2016, the TB cluster location only included the Kemiling subdistrict. Therefore, the locations of the TB clusters shifted between 2015 and 2016. This result is in line with the findings reported in studies conducted in Antananarivo, Madagascar, and Linyi, China, which also found that the location of the TB clusters shifted.[9,22] However, the present study results differ from the findings reported in a study conducted in Barcelona, Spain, which found that most of the space–time clusters were located in the same area.[23] The difference in these findings could be because Spain has a low incidence of TB and only certain locations in that country had a high incidence of TB.[23] In contrast, Indonesia is a country with a high TB burden, and most areas have a high incidence of TB.

In the present study, although the location of the TB clusters shifted, the TB clusters in 2015 and 2016 had similar low social determinants. In 2015, the significant clusters were located in areas with a high population density; in 2016, the cluster was located in areas with a middle–high population density. A study conducted in Beijing also found that high population density was the major factor associated with the TB cluster in that city.[24] This result also indicates that TB in Bandar Lampung, Indonesia, is distributed unequally based on high and middle population density. Previous research conducted in Bandar Lampung reported that most TB patients in that city live in overcrowded housing and overcrowded neighborhoods, which also increases the risk of TB being transmitted.[25]

Furthermore, in 2015 and 2016, the TB clusters were located in areas in which the percentage of poverty was either low or middle, not in areas with a high percentage of poverty. The cluster areas are located at the center of Bandar Lampung or in trading and industrial areas, which are more likely to have a clustered migrant population with a low socioeconomic status. A study conducted in Hermosillo, Mexico, reported that, due to demographics and urbanization, most of the population was concentrated in the middle- and upper-class areas, which also have a middle and low percentage of poverty, respectively. Moreover, the residences with low socioeconomic status are clustered in certain sections of the studied areas.[21] A study conducted in China also showed that the migrant population

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**Table 1: Spatio-temporal clusters of tuberculosis (2015) in Bandar Lampung**

| Cluster               | n  | Observed/expected | Expected | P         | Remarks       |
|----------------------|----|-------------------|----------|-----------|---------------|
| Most likely cluster  | 94 | 1.65              | 56.99    | 0.000021  | Significant   |
| Secondary cluster (2)| 184| 1.32              | 139.79   | 0.0021    | Significant   |
| Secondary cluster (3)| 7  | 3.18              | 2.20     | 0.974     | Not significant |

**Table 2: Spatio-temporal clusters of tuberculosis (2016) in Bandar Lampung**

| Cluster               | n  | Observed/expected | Expected | P         | Remarks       |
|----------------------|----|-------------------|----------|-----------|---------------|
| Most likely cluster  | 15 | 3.11              | 4.83     | 0.025     | Significant   |
| Secondary cluster (2)| 13 | 2.84              | 4.57     | 0.286     | Not significant |
| Secondary cluster (3)| 166| 1.27              | 131.16   | 0.450     | Not significant |
contributed to a high TB prevalence and a significant number of TB clusters.\(^2\)\(^1\)

In the present study, cluster dynamics included the size of the clusters. In 2015, the first (most likely) cluster radius was 4.40 km with 94 TB cases; the secondary cluster 2 radius was 2.21 km with 184 TB cases. In 2016, the cluster radius was 1.98 km with 15 TB cases. The results show that, in 2015, the clusters covered a wider area and had more TB cases than the cluster in 2016. In 2015, for every 1 km radius, there were approximately 84 TB patients. In 2016, for every 1 km radius, there were approximately eight TB patients.

Research conducted in the United States showed that the clusters with the highest TB incidence rate versus the expected incidence rate also had the highest number of matching isolates. A study conducted in Montreal, Canada, also showed that areas with a high incidence of TB also had the same genotyping. The findings of both research studies imply that a cluster with a high number of TB patients tends to have local TB transmission.\(^2\)\(^6\)\(^7\)

Based on the results presented above, the spatio-temporal dynamics in the TB clusters in 2015 and 2016 included the number of clusters, the number of TB cases in the cluster, the cluster location, and the cluster size. Moreover, the TB clusters had similar social determinants: a middle–high population density and a low–middle percentage of poverty. The cluster with a TB incidence also implies the possibility of local transmission. The spatio-temporal dynamic information about TB clusters is very useful in supporting a TB control program, especially in high-burden TB countries, with a high population density and a high percentage of poverty.

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Conflicts of interest

There are no conflicts of interest.

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