

Brief Original Article

First exploratory spatial distribution analysis of tuberculosis and associated factors in Tonalá, Mexico

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Abstract

Introduction: The US-Mexico region is at high risk of elevated tuberculosis (TB) incidence due to mobility and migration. Knowledge of how socio-demographic factors varies geographically, provides clues to understanding the determinants of tuberculosis and may provide guidance for regional prevention and control strategies to improve public health in Mexico. The aim of the present study was to describe the epidemiologic characteristics and spatial patterns of the incidence of tuberculosis in Tonalá, Jalisco (Mexico) from 2013–2015.

Methodology: The Surveillance System Database from the Health Department, complemented by information from the National Institute of Statistics and Geography, was used to obtain data for a spatial-temporal analysis of TB cases. For the geographical analysis map creation and geoinformation storing, ArcGIS software was used.

Results: This study sought to characterize problem areas and jurisdictional locations of TB via a spatial approach based on analyses of case distributions and individual patient variables. The study found that tuberculosis cases were dispersed throughout Tonalá County and were mainly concentrated on the Guadalajara city border. The TB cases were mainly individuals between 31 and 45 years old. Most of the cases reported during the observation period were male patients, and most cases primarily had lung involvement; however, there were quite a few cases with lymph node and intestinal disease.

Conclusion: Our findings show that TB cases are essentially located in areas close to the city of Guadalajara and that most TB cases were pulmonary cases spread throughout the whole jurisdiction.

Key words: Tuberculosis; spatial distribution; risk factors; Mexico.

J Infect Dev Ctries 2020; 14(2):207–213. doi:10.3855/jidc.11873

(Received 25 July 2019 – Accepted 29 January 2020)

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Introduction

Tuberculosis (TB) remains a major public health issue in the world. The WHO estimated 282,000 new and relapsed TB cases for the Americas in 2017. Infectious disease transmission along the U.S.–Mexico border is an area of particular concern. In Mexico, tuberculosis has become a serious public health problem, mainly due to the appearance of multidrug-resistant strains (MDR) and comorbidities, such as diabetes mellitus. In 2017, more than 28,000 new cases of TB occurred in Mexico, with more than 2,000 deaths [1].

Several studies have used GIS as a strategy for the jurisdictional characterization of TB patterns by

evaluating disease concentration case responses and designing strategies for TB control [2,3]. Health departments are developing many diverse approaches that may influence decision makers.

The worldwide prevalence of TB is mainly associated with social inequality, poverty, overcrowding and migration [4]. According to the Institute of Mexicans Abroad, through the issuance of high security consular registration plates, 814,000 new migrants in the United States were registered in 2016; of this total, 7.5% are from Jalisco. During 2017, there were 60,767 new migrants from Jalisco in the United States [5].

Previous studies have found both individual-level and neighbourhood-level sociodemographic factors to be predictors of TB transmission [6]. Individual-level sociodemographic characteristics include younger age, minority race/ethnicity status and male sex. Neighbourhood-level characteristics include population density and age composition, and relative neighbourhood sociodemographic status has been considered a predictor at both the individual and neighbourhood levels [7-8]. Thus, knowledge of the spatial distribution of TB and epidemiology of TB are essential in developing public health strategies for effective control [9].

In Mexico, several challenges faced by TB control programmes at the local level are related to the early detection of infection and identification of cases, as well as difficulties in recording the outcomes of the treatment of cases, such as the rate of cured cases, dropouts, failure to treat, transferred cases, completed treatment cases and deaths [10]. Moreover, few studies performed to date have characterized the sociodemographic factors and clinical manifestations associated with tuberculosis in Mexico. In this study, we describe the epidemiologic characteristics and spatial patterns of the incidence of tuberculosis in Tonalá, Jalisco (Mexico), from 2013-2015.

Methodology

Study Setting

The city of Tonalá is located in the eastern centre of the state of Jalisco in Mexico, with the coordinates 20°31'50" to 20°42'10" north latitude and 103°08'30" to 103°16'50" west longitude, at an average height of 1,500 metres above sea level. It borders Zapotlanejo to the north; El Salto and Juanacatlán to the south; San Pedro Tlaquepaque and Guadalajara to the west; and Zapotlanejo to the east. Its territory extends 166.1 km² and has a population of 536,111 people (2015) [11]. In 2010, 6.8 percent of the Tonalá population lived in extreme poverty, and in 2015, it decreased to 3.9 percent of the Tonalá population, which is equivalent to 21,008 people living in extreme poverty [12].

Data Collection

Exploratory spatial analysis was performed in Tonalá, Jalisco, in Mexico to analyse the demographic characteristics, known TB risk factors, and clinical and neighbourhood characteristics of TB in this state at the county level. Geocoding methodology was used to study the jurisdictional characteristics. No previous characterization of the spatial-temporal distribution of TB cases has been reported in this area.

A case database was provided by the Health Ministry of Jalisco, Mexico, to analyse the jurisdictional/district characteristics of TB cases. During the processing of the information, sociodemographic and clinical data were analysed to determine the significant locations where TB could be spread. The Surveillance System Database from the Health Department collects several risk factors from TB cases, and this study included factors such as county, address, institution, localization of bacteria in the body, diagnosis date, treatment start date, treatment round, type of patient, status of the patient, and number of people infected by the original case. This study was complemented by information from the National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía "INEGI" <http://www.inegi.org.mx/>) and the National Council of Population (Consejo Nacional de Población "CONAPO" <https://www.gob.mx/conapo>).

The data obtained were analysed in the statistical software package R© (<https://www.r-project.org/>) for normalization and analysis. To identify problem areas, the dataset was filtered, and then, the address of the cases was used to perform a geocoding process to transform the address into longitude/latitude coordinates. To perform geocoding for TB in Tonalá and determine the locations of TB problem areas, a new field was created in the database that contained the full address of the patient (street name, zip code, neighbourhood, and municipality). This occurred throughout the country; therefore, many details must be included in the address field to generate the best results possible. A second review was further performed after the geocoding step was executed to verify whether the coordinates obtained were consistent with the address stated for the patient.

Data Processing

For geographical analysis, map creation and geoinformation storing, ArcGIS© 10.2.2 software was used. The shapefile generated by the geocoding was projected for fitting with the additional layers available in the programme. A geodatabase was created to generate more robust regulation over the geoinformation. The geodatabase was completed with several layers to create comparisons of new and previous official information. To generate a general overview of the information available, several maps were created [13].

Results

Distribution of tuberculosis cases in Tonalá County

In 2016, 139 new cases of tuberculosis were detected in Jalisco during the first three months of the year (Health Ministry of Mexico, 2016). The geocoding data results showed the geographical distribution of TB cases from 2013-2015, with 366 total cases analysed. This study included 113 (30.8%) cases in 2013, 111 (30.3%) cases in 2014 and 142 (38.7%) cases in 2015. The observation area was limited to cases identified in the county of Tonalá. The Health Department recognizes boundaries that are different from the formal municipal borders; therefore, this county includes more than one municipality. The cases were consistently concentrated in the northwest part of the city over the three-year period observed (Figure 1). During 2015, most of the cases appeared to be located on the northwest side of Tonalá near the border shared with

Guadalajara. During 2014, a slight decrease in disease cases occurred; however, in 2015, the number of tuberculosis cases increased considerably. This study may provide guidance for regional prevention and control strategies to improve public health in Mexico.

Spatial-temporal patterns of patients by age and gender

The ages of the patients at the time of tuberculosis diagnosis based on the distribution of TB cases from 2013-2015 were analysed. We found that the proportion of cases in the age range of 1 to 15 years (4%) did not change, and cases less than one year of age had the lowest proportion observed throughout the observation period. The largest number of TB cases in Tonalá from 2013-2015 was in the age range of 31 to 45 years, representing 33.6% of all cases (Table 1). The geospatial distribution was co-analysed with the frequency distribution.

Figure 1. Distribution of tuberculosis cases in Tonalá County. Spatial distribution of tuberculosis cases from 2013-2015 analysed spatially showed marked TB distribution in Tonalá, near the border shared with Guadalajara.

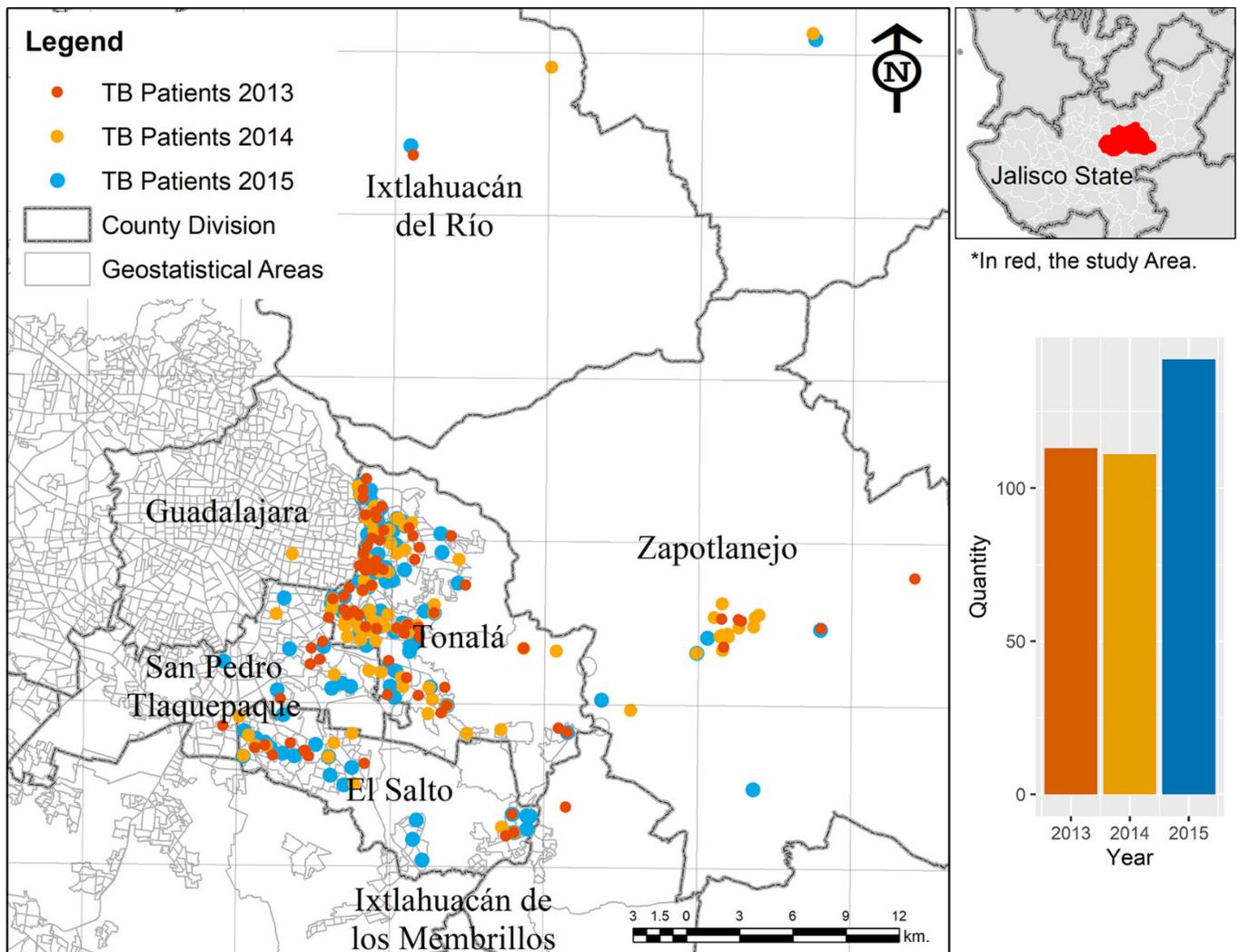


Table 1. Frequency of treatment outcome in patients with tuberculosis. Low frequency of complete treatment is observed during the study period, 2013 -2015.

	2013		2014		2015		Total
	Cases	Frequency (%)	Cases	Frequency (%)	Cases	Frequency (%)	Frequency n (%)
Cured	68	60	66	59	48	34	182 (50)
Treatment completed	29	26	24	21	20	14	73 (20)
Treatment failed	2	2	9	8	53	37	64 (17)
Died	8	7	8	7	9	6	25 (7)
Loss to follow-up	6	5	3	3	11	8	20 (5)
Not evaluated	0	0	1	1	1	1	2 (1)
Total	113	100	111	99	142	100	366 (100)
Treatment success (cured + treatment completed)	97	86	90	81	68	48	303 (70)

Spatial analysis of the data categorized by gender throughout the analysis period showed that the incidence of tuberculosis was lower in 2014 than in 2015 and 2013 (Table 1). Male patients had a higher incidence (70%) than female patients (29%).

Treatment outcomes in patients with tuberculosis

Treatment predefined outcomes for TB patients during 2013-2015 were analysed in the study population including, cured (50%), treatment completed (20%), treatment failed (17%), died (7%), loss to follow-up (5%) and treatment success (70%) (Table 2). The treatment outcome analysis find out that half of the patients were cured after the treatment. Our results highlight a moderate cure rate in concordance with other studies in countries as India [14]. However other estimates from Africa and Russia suggest that treatment fails to cure 30–75% of patients with drug-resistant tuberculosis, which indicate an increasing incidence of drug-resistant tuberculosis reported by WHO [15-16].

Location of disease

Analysis of the distribution of TB cases during the three-year study period and the localization of bacterial infection was performed. A total of eleven different localizations of disease were reported to the Health Department (Figure 2). Most of the cases were pulmonary (72%); however, there were several cases of lymph node (13%) and intestinal disease (5%). Only two cases of ocular infection were reported (1%).

During 2013, tuberculosis in the lungs was present in most cases (74%), followed by lymph node infection (9% of cases). In 2014, most of the cases included pulmonary tuberculosis (76%). In specific areas, we found increased incidences of lymph node infection (18%). Meanwhile, of the 142 total cases reported in 2015, pulmonary disease retained the highest proportion of cases (72%). However, a greater diversity of infection areas was observed in 2015 than in the previous two years (Figure 2).

This study shows that most cases of TB were pulmonary cases spread throughout the whole jurisdiction. In Zapotlanejo, patients with lymph node infection were localized to the centre of town, in

Table 2. Characteristics of patients with tuberculosis in Tonalá, Mexico 2013 -2015.

Age (years)	2013		2014		2015		Total
	Cases	Frequency (%)	Cases	Frequency (%)	Cases	Frequency (%)	Frequency n (%)
0-15	5	4	6	5	5	4	16 (4)
16-30	26	23	24	21	41	29	91 (25)
31-45	42	37	35	32	46	32	123 (33)
46-60	24	21	30	27	30	21	84 (23)
over 60	16	14	16	15	20	14	52 (14)
Total	113	99	111	100	142	100	366 (99)
Gender							
Female	29	26	41	37	37	26	107 (29)
Male	84	75	70	63	105	74	259 (70)
Total	113	101	111	100	142	100	366 (99)

addition to several lung infection cases. In the municipality of Tonalá, the infection localization was randomly distributed over the whole city.

Discussion

Epidemiologic and sociodemographic factors collectively define Mexico as a high-priority country for TB control in the Americas [17-19]. In this study, some factors related to the development of TB [20-21], as well as the diversity of infection localization [22-23], were studied at the town level in Jalisco. Moreover, no previous studies performed in Mexico have analysed the spatial distribution of cases at the individual level, as well as the sociodemographic characteristics of tuberculosis patients.

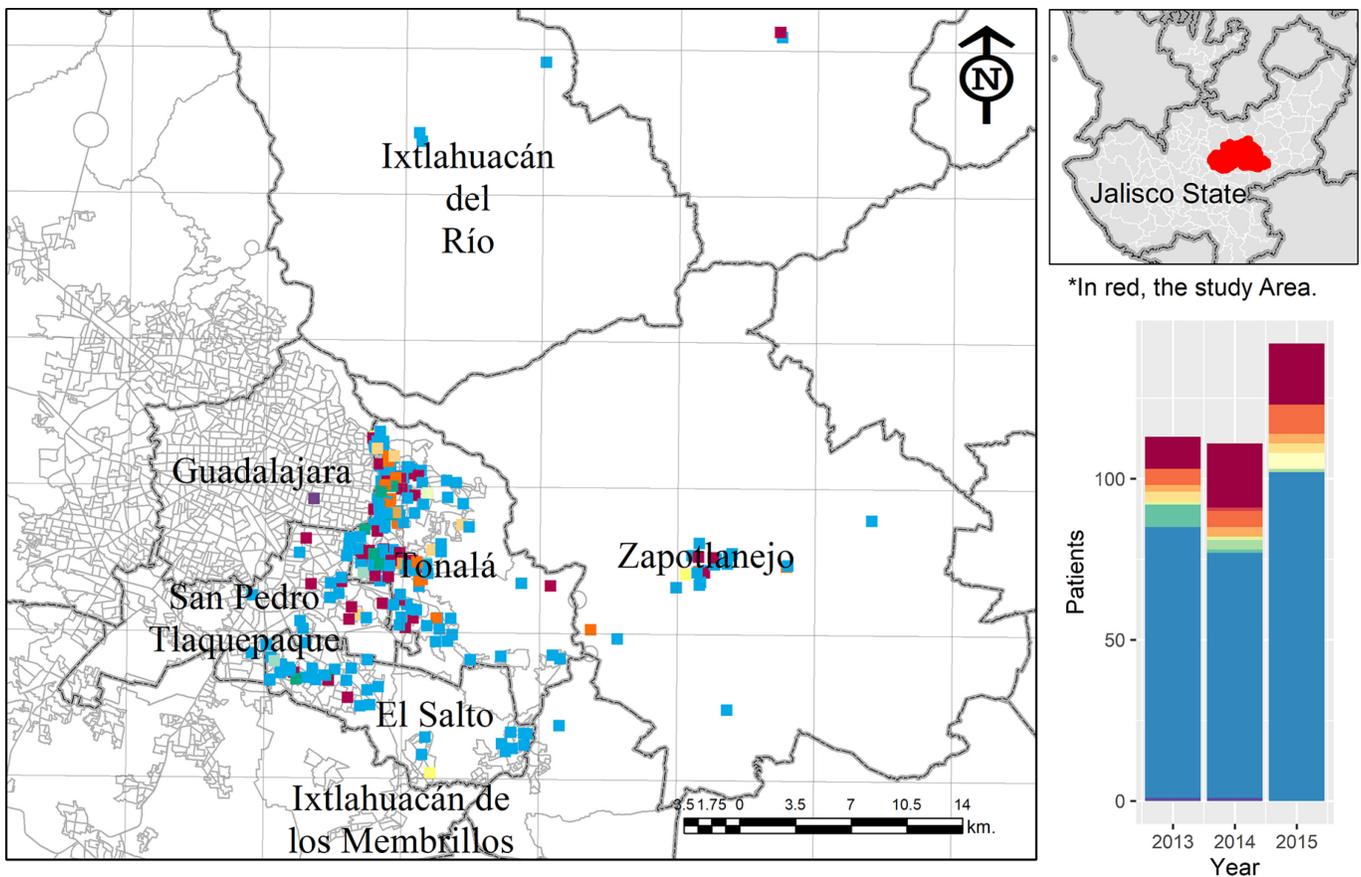
The TB cases seem to be primarily located in the areas close to the city of Guadalajara. It could be

estimated that these areas tend to be urban, with a higher population density, whereas areas where the other cases are distributed have a much lower population density. The control of tuberculosis in this region will require the promotion of emergent health programmes.

The analysis showed that the highest incidence of tuberculosis was in patients 31-45 years old, which constituted the most active segment of society [24], consistent with previous studies that identified middle age as associate factor for TB [25-26]. These results can aid in the design of high-priority control efforts.

This study contributed to the spatiotemporal analysis of TB incidence in Tonalá, Jalisco (Mexico), yet it has certain limitations. The data were extracted from official surveillance data, which cannot exclude the possibility of cases being underreported in some regions. Cases may be missed by routine notification

Figure 2. Location of disease. Since TB can be located in different organs in the body, the relationship between the organ location and year was spatially analysed. There was an increase in 2015 in pulmonary tuberculosis cases, primarily located along the border with Guadalajara.



Legend

- Ganglion
- Intestinal
- Miliary
- Eye
- Others
- Kidney
- Genito-Urinary
- Meninges
- Mixture
- Bones
- Longs
- County Division
- Geostatistical Areas

systems because persons afflicted with TB often do not seek care, remain undiagnosed or are diagnosed by private providers that do not report TB cases to local or national authorities when they do seek care [24-29].

The distribution of TB cases in Tonalá was determined by the geocoding methodology. The knowledge generated by this study may provide guidance for regional prevention and control strategies to improve public health in Mexico.

Conclusion

Tuberculosis remains a significant public health burden in the state of Jalisco, and our findings show that there are significant spatial and temporal characteristics of TB at the town level in the region. TB cases are essentially located in areas close to the city of Guadalajara, and most cases of TB were pulmonary and spread throughout the whole jurisdiction. Therefore, the findings of this study provide useful information concerning the prevailing epidemiological status of TB in Tonalá using existing health data and could be used to develop strategies for more effective TB control at the town level. As strategies for better control of TB, state programs include diagnosis, follow-up, treatment and control of cases. There are case promoters and contact studies, with intra and extra home visits, then our findings can help to geographically referenced health databases present unprecedented new opportunities to investigate social and behavioral factors underlying geographic variations in disease rates at small-area scale.

Funding

This study was supported with funds provided by CONACYT through grant PDCPN_2014_247879, Scientific Development Projects to Attention National Problems.

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Conflict of interests: No conflict of interests is declared.