


# Space–time clustering and temporal trends of hospitalizations due to pulmonary tuberculosis: potential strategy for assessing health care policies

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**Background:** Tuberculosis (TB) causes pressure on healthcare resources, especially in terms of hospital admissions, despite being considered an ambulatory care-sensitive condition for which timely and effective care in ambulatory setting could prevent the need for hospitalization. Our objectives were to describe the spatial and temporal variation in pulmonary tuberculosis (PTB) hospitalizations, identify critical geographic areas at municipality level and characterize clusters of PTB hospitalizations to help the development of tailored disease management strategies that could improve TB control. **Methods:** Ecologic study using sociodemographic, geographical and clinical information of PTB hospitalization cases from continental Portuguese public hospitals, between 2002 and 2016. Descriptive statistics, spatiotemporal cluster analysis and temporal trends were conducted. **Results:** The space–time analysis identified five clusters of higher rates of PTB hospitalizations (2002–16), including the two major cities in the country (Lisboa and Porto). Globally, we observed a –7.2% mean annual percentage change in rate with only one of the identified clusters (out of six) with a positive trend (+4.34%). In the more recent period (2011–16) was obtained a mean annual percentage change in rate of –8.12% with only one cluster identified with an increase trend (+9.53%). **Conclusions:** Our results show that space–time clustering and temporal trends analysis can be an invaluable resource to monitor the dynamic of the disease and contribute to the design of more effective, focused interventions. Interventions such as enhancing the detection of active and latent infection, improving monitoring and evaluation of treatment outcomes or adjusting the network of healthcare providers should be tailored to the specific needs of the critical areas identified.

## Introduction

With just over 280 000 cases reported in 2017, it is clear that tuberculosis (TB) still poses a public health threat in the World Health Organization (WHO) European Region, despite the notable progress achieved in the region.<sup>1</sup> The average annual decline in the TB incidence rate was 4.7% (2008–17), which is the fastest decline among all WHO regions, but still there is a long way to accomplish the End TB Strategy milestones.<sup>1</sup>

Following the trend of the European Region, Portugal has seen a constant reduction in the number of notified TB cases<sup>2</sup> but still has one of the highest TB incidence rates in the European Union (EU), only surpassed by countries of Eastern Europe.<sup>1</sup>

The risk of progression to infection and disease is frequently associated with characteristics such as HIV infection, drug and alcohol abuse, immigrants from higher prevalence regions or poor living conditions, risk normally present in the most vulnerable populations in the urban areas.<sup>3–6</sup> The fact that these characteristics tend to concentrate in big cities may explain why cases are not evenly distributed in geographical and time units.<sup>7</sup>

TB causes a tremendous strain on healthcare resources, particularly in terms of hospital-based treatment and extended hospitalization. Nonetheless, TB is considered an ambulatory care-sensitive condition (ACSC)<sup>8–10</sup> meaning it is considered a condition for which timely and effective management and treatment in ambulatory setting could potentially reduce or even avoid the need for hospitalization.<sup>11,12</sup> Treatment of TB patients should be carried out through ambulatory care (health care facility-based or

home-based),<sup>13</sup> with inpatient treatment care reserved for cases of greater clinical severity, existence of comorbidities or conditioning of the treatment regimen.<sup>14</sup> TB hospitalizations can reflect the evolution of the disease in the community and can mirror the heterogeneity of geographical and temporal distribution of TB cases, but other important factors can interact in this relation, namely differences in primary health care services (in quality or/and availability) and differences in patient profiles (sociodemographic characteristics, clinical complexity).

Spatial and space–time clustering analysis detects event clusters, identifying areas with a number of events that exceed those expected.<sup>7,15</sup> From a health management point of view, understanding the spatial and temporal variation in the dissemination of TB could result in the development of distinctly adapted control strategies, which would improve their impact on morbidity and mortality.<sup>16</sup> In addition, since time trends may be different in distinct geographic regions, knowledge about these differences may indicate where disease prevention and control measures are successfully implemented or where control measures are not having the desired impact.<sup>17</sup>

In countries with a good TB surveillance system, such as Portugal, a spatial and spatiotemporal analysis can play an important role in the identification of areas with relevant epidemiological phenomena, thus constituting an important resource in terms of public health knowledge and support to strategic interventions.<sup>18–20</sup> Knowing the spatial and temporal trends of PTB hospitalizations, through describing how critical incidence areas evolve and characterizing distinct regional time trends, can provide crucial information for implementing better control strategies.

This study aimed to contribute to improve public health management, focusing in the PTB hospitalizations, as it is the form of the disease responsible for most part of the transmission between individuals, in continental Portugal between 2002 and 2016. The specific objectives were to (i) investigate the temporal trend of PTB hospitalizations; (ii) identify space–time clusters of PTB hospitalizations at municipality level; (iii) identify areas with different temporal trends in national context and (iv) characterize clusters of PTB hospitalizations considering gender, age, days of hospitalization and cause of diagnosis (PTB as principal or secondary diagnosis).

## Methods

### *Study design and data source*

Ecologic study that used data from the nationwide hospitalization database of Portugal was provided by the Central Administration of Health System of the Portuguese Ministry of Health. These data included sociodemographic, geographical and clinical information of PTB hospitalization episodes in continental Portuguese public hospitals between 2002 and 2016. All inpatients with a principal or secondary diagnosis of PTB coded according to the International Classification of Diseases (ICD 9: 011.xx) were included in the study. Principal diagnosis represents the clinical condition responsible for the hospitalization and secondary diagnosis describes those conditions detected at the time of admission or that develops subsequently, that were not the cause of the hospitalization.<sup>21</sup> Population in each municipality by year, gender and age was obtained from the Statistics Portugal, the official national institute of statistics.

Ethics committee approval and informed consent were not required, as all data used were based on official databases previously anonymized.

### *Study data and statistical analysis*

A detailed descriptive analysis of PTB hospitalization episodes included several sociodemographic and clinical variables—gender, age, length of stay (LOS), diagnosis (principal or secondary), year of hospitalization and municipality. Regarding LOS, only the hospitalizations with <365 days were considered in the analysis. Each municipality was defined as rural (<150 inhabitants/km<sup>2</sup>) or urban area (>150 inhabitants/km<sup>2</sup>).<sup>22</sup> The annual rate of PTB hospitalizations/10<sup>5</sup> population at a municipality level ( $n = 278$ ) was calculated considering the annual number of reported PTB hospitalizations by municipality of residence of each patient (numerator) and the population of each municipality (denominator). The statistical analysis was performed using IBM® SPSS® Statistics for Windows 23.0.

### *Spatiotemporal cluster analysis and temporal trends*

The analysis was performed for the entire study period (2002–16) and for a more recent period (2011–16) to discover the consistency of clusters found and the respective short trends. The spatial scan analysis was performed using SaTScan<sup>TM</sup> 9.4.

Two different approaches were used to identify clusters based in Kulldorff's spatial scan statistic<sup>23</sup>: (i) classical space–time clustering of hospitalizations—retrospective analysis of spatiotemporal clustering to investigate the areas with the highest PTB hospitalizations per 100 000 population at municipality level and (ii) spatial variation in temporal trends clustering—observation of evolution trends of PTB hospitalizations, regarding the increase or decrease of incidence in the same period.

Kulldorff's spatial scan statistic uses moving circular windows of varying diameter to evaluate clusters. For each specified location, a series of circles of varying radii are constructed. The radius of each circle is set to increase continuously from zero to an upper limit set by the user. For each circle location and size, the software compares

a value inside the circle to the value outside the circle. For each location and size of the scanning circular window, the alternative hypothesis was that there was an elevated risk of disease within the circle compared with the outside. When looking for clusters in space and time the idea of a two-dimensional circular window is extended to that of a cylinder passing through time.

The probabilistic model used for searching clusters was the discrete Poisson model, with 20% of the population at risk, circular window shapes and no geographical overlap between clusters. With the discrete Poisson model, the number of cases is compared with the background population data and the expected number of cases in each area is proportional to the size of the population at risk or to the person-years in that area.<sup>23,24</sup>

Monte Carlo simulation with 999 permutations was used to determine the statistical significance of the clusters ( $P$  values). Only clusters with  $P$  values <0.05 were included in the analysis. The relative risk and log likelihood were also calculated for each cluster.

## Results

Between 2002 and 2016, in public hospitals in continental Portugal, there were 22 760 cases of hospitalization due to PTB with more than half of these patients presenting PTB as the principal diagnosis ( $n = 16\ 643$ ; 60.0%). 74.2% ( $n = 20\ 610$ ) of the patients were male and presented a mean ( $\pm$  standard deviation) age of 48.2 years ( $\pm 18.7$ ), ranging from <1 to 108 years. Descriptive analyses of PTB hospitalizations episodes in continental Portugal (2002–16) are presented in [Supplementary table S1](#).

In terms of LOS, 25% of the hospitalizations lasted up to 7 days ( $n = 7359$ ), 50% lasted up to 16 days ( $n = 14\ 428$ ) and 75% went on for up to 30 days ( $n = 20\ 853$ ), which resulted in a median number of days of inpatient care of 16.0 ( $\pm 29.9$ ) days. In six cases, the time of hospitalization was missing and 30 patients (0.1%) were hospitalized for more than a year (>365 days).

The overall hospitalization rate between 2002 and 2016 was 17.7/10<sup>5</sup> per year, with hospitalization rates decreasing by 64.9% during this period (2002: 29.4/10<sup>5</sup>; 2015: 9.6/10<sup>5</sup>). The percentage of cases in which PTB was the main diagnosis was always greater than the number of cases in which PTB was a secondary diagnosis, although over the years the difference has been narrowing (2002: 5.1%; 2016: 2.2%; [Supplementary figure S1](#)). Between 2010 and 2011, there was a slight increase in the rate of PTB hospitalizations, although the rates resumed their downward trend. This increase led us to divide the cluster analysis into two periods, 2002–16 (overall analysis) and 2011–16 (more recent period).

Of the 27 760 hospitalizations, 27 115 (97.7%) had information about the municipality where the patient resided. A table with descriptive analysis of incidence rates: municipalities with the highest or the lowest PTB hospitalization rates, as well as averages, median and standard deviations for each year, from 2002 until 2016, is presented in [Supplementary table S2](#). The municipality with the highest rate of hospitalization for PTB varied over time except in 2008 and 2010, years in which Vila do Bispo presented the maximum rate. The rate of municipalities without patients hospitalized with PTB increased over time (2002—67 municipalities and 2016—108 municipalities) while the mean and median decreased.

Most municipalities with the highest rates are rural areas, with the exception occurring in 2002, 2004 and 2007 where urban areas presented the maximum rate.

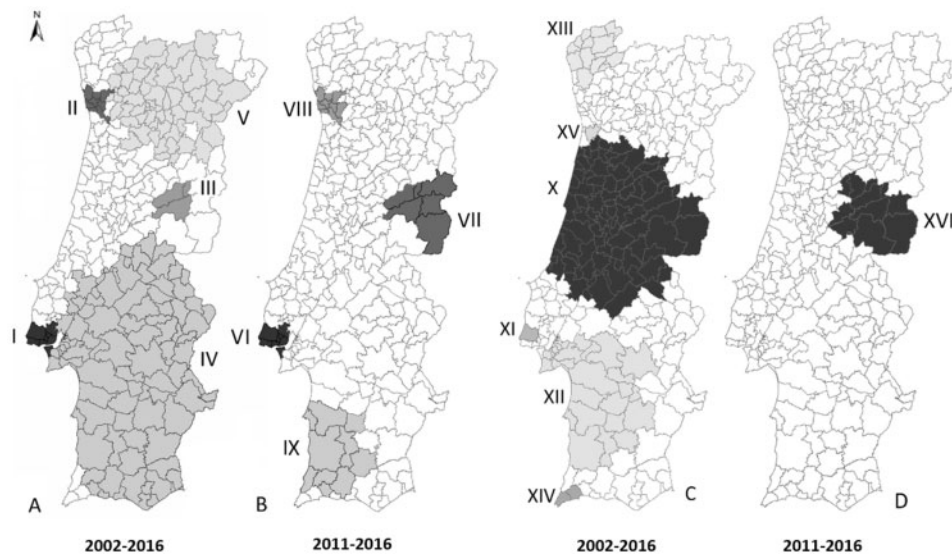
Globally, the municipalities of Lisboa and Porto presented the highest number of episodes of PTB hospitalizations (Lisboa,  $n = 3530$  and Porto,  $n = 1556$ ) and the highest rates of PTB hospitalizations. Lisboa presented a mean (minimum–maximum; standard deviation) rate of hospitalizations of 43.0 (18.8–83.6; 21.3) and Porto a mean rate of hospitalizations of 42.3 (8.9–84.48; 21.6).

**Table 1** Space–time cluster information on PTB hospitalization rates in two different periods, 2002–16 and 2011–16, in continental Portugal

Time period	Cluster (P-value)	Time frame	Number of cases (number of municipalities)	Rural/urban region (%)	PTB hospitalization rate <sup>a</sup>	Relative risk	Log likelihood
2002–16	I (<0.001)	2002–04	3025 (8)	Urban (100)	51.5	3.19	1351.0
	II (<0.001)	2002–04	1302 (8)	Urban (100)	43.6	2.58	423.27
	III (<0.001)	2014–16	103 (3)	Rural (100)	41.4	2.38	29.45
	IV (<0.001)	2002–04	1247 (88)	Rural (84.1)	21.6	1.25	27.10
	V (<0.001)	2002–02	312 (59)	Rural (78.0)	25.7	1.48	20.74
2011–16	VI (<0.001)	2011–11	552 (8)	Urban (100)	27.6	2.37	150.18
	VII (<0.001)	2015–15	50 (6)	Rural (100)	46.2	3.82	29.96
	VIII (<0.001)	2011–11	228 (9)	Urban (100)	21.0	1.75	29.29
	IX (0.002)	2011–11	53 (10)	Rural (90.0)	27.1	2.24	13.31

For each cluster, the *P* values, time frame (years), number of cases, number of municipalities, type of area (rural/urban), PTB hospitalization rate (PTB hospitalizations/10<sup>5</sup> population), relative risk and log likelihood are presented.

<sup>a</sup> PTB hospitalizations rates – PTB hospitalizations/10<sup>5</sup> population.



**Figure 1** Space–time clusters (A and B) and space clusters of temporal trends (C and D) of PTB hospitalization rates divided in two periods: 2002–16 (overall analysis) and 2011–16 (recent period).

Space–time clusters of higher rates of PTB hospitalizations is shown in table 1 and figure 1A and B. When space–time clustering was applied to the overall period of the study (2002–16) five different clusters were identified, with the clusters in Lisboa (Cluster I) and Porto (Cluster II) metropolitan areas presenting the highest rates and observed/expected ratios (2.95 and 2.50, respectively). Applying the same analysis to the period from 2011 to 2016, four clusters were observed with Lisboa metropolitan area (Cluster VI) and a northeast rural region (Cluster VII) presenting the highest rates and observed/expected ratios (2.27 and 3.80, respectively).

Regarding the spatial variation in temporal trends of PTB hospitalizations, table 2 and figure 1C and D represent the results for the two periods studied and their spatial distribution, respectively.

During the 2002–16 period, was observed a –7.2% mean annual percentage change in rate with only one of the clusters identified presenting an increase trend—Cluster XIV (+4.34%). In the more recent period (2011–16) was obtained a mean annual percentage change in rate of –8.12% with the only cluster identified in this period displaying an increase trend (+9.53%). Progression of the rate of PTB hospitalizations per 100 000 population in the clusters of temporal trends are presented in Supplementary figures S2 and S3 and the descriptive analysis of PTB hospitalizations per cluster (trends analysis) is showed in table 3.

The majority of the municipalities ( $n = 142$ ) included in the clusters identified in both time periods studied is rural areas ( $n = 114$ , 80.3%).

## Discussion

Over the past decades, Portugal has accomplished a steady decline in the number of TB cases, having reached and maintained a TB incidence below 20 cases per 100 000 population since 2015.<sup>2,25</sup> In our study, the rates of PTB hospitalization in continental Portugal reflected this trend, presenting a constant decrease through the 15 years studied (2002–16). The only exception was in 2011 where we observed a slight increase in the hospitalization episodes, however in the years after the rates resumed their downward trend. Portugal was affected by the global financial crisis and this increase in 2011 may reflect the policy of austerity adopted in Portugal, which was accompanied by a worsening of access to health care.<sup>26,27</sup> This may have led, especially in the first years of the crisis, to a greater number of people seeking access to health care only when the situation became critical, consequently leading to a higher number of hospitalizations. However with implementation of a comprehensive set of structural reforms to work towards economic sustainability, improved efficiency and better quality of the healthcare system<sup>28</sup> the rates resumed their downward trend.

Globally, even though presenting a decreasing trend, Lisboa and Porto urban areas showed the highest number of episodes and rates of PTB hospitalizations during the period of the study (2002–16). These results are in line with studies that focused on the incidence of PTB in mainland Portugal and found that the urban areas of Lisboa and Porto were the most critical regions in terms of pulmonary TB (PTB).<sup>7,29</sup> On the other hand, we observed an increasing number of

**Table 2** Space clusters of temporal trends of PTB hospitalization incidence rates observed in the periods 2002–16 and 2011–16

Time period	Cluster (P-value)	Number of cases (number of municipalities)	Rural/urban region (%)	Trends inside/outside (%)	PTB hospitalization rate <sup>a</sup>	Relative risk	Log likelihood
2002–16	X (0.001)	3426 (88)	Rural (81.8)	−3.63/−7.45	11.1	0.59	51.23
	XI (0.001)	1224 (1)	Urban (100)	−2.04/−7.45	21.7	1.25	34.54
	XII (0.001)	2183 (24)	Rural (79.2)	−4.28/−7.45	17.0	0.97	20.47
	XIII (0.001)	728 (14)	Rural (71.4)	−2.85/−7.32	11.0	0.62	14.24
	XIV (0.001)	98 (2)	Rural (100)	+4.34/−7.24	18.7	1.07	12.32
	XV (0.03)	301 (2)	Urban (100)	−1.9/−7.2	12.5	0.71	8.59
2011–16	XVI (0.001)	243 (11)	Rural (100)	+9.53/−8.65	19.3	1.61	11.27

For each cluster, the *P* values, number of cases, number of municipalities, type of area (rural/urban), trends inside/outside the cluster (%), PTB hospitalization rate (PTB hospitalizations/10<sup>5</sup> population), relative risk and log likelihood are presented. Negative and positive percentages correspond to decreasing or increasing trends, respectively.

<sup>a</sup>: PTB hospitalizations rates – PTB hospitalizations/10<sup>5</sup> population.

**Table 3** Descriptive analyses of PTB hospitalizations per cluster (trends analysis) according to gender, age (years), LOS (days) and number of cases with PTB as principal diagnosis

Time period	Clusters (number of cases)	Gender		Age (years)		LOS (days)		Cases with PTB as principal diagnosis, <i>n</i> (%)
		Male, <i>n</i> (%)	Female, <i>n</i> (%)	Min–Max	Mean/median (SD)	Min–max	Mean/median (SD)	
2002–16	X (3426)	2514 (73.5)	907 (26.5)	2–99	52.6/50.0 (19.3)	0–307	23.0/16.0 (26.6)	2336 (68.3)
	XI (1224)	826 (67.5)	397 (32.5)	1–99	41.8/40.0 (17.3)	0–300	23.4/15.0 (31.4)	764 (62.5)
	XII (2183)	1572 (72.0)	611 (28.0)	1–99	48.4/46.0 (18.3)	0–327	28.7/20.0 (30.7)	1529 (70.0)
	XIII (728)	554 (76.0)	175 (24.0)	1–94	51.6/50.0 (19.0)	0–231	21.2/15.0 (22.0)	486 (66.7)
	XIV (98)	78 (79.6)	20 (20.4)	9–95	49.6/47.5 (19.6)	0–129	28.8/21.5 (26.9)	72 (73.5)
	XV (301)	232 (72.1)	69 (22.9)	1–92	47.8/45.0 (18.9)	0–351	21.3/13.0 (31.6)	194 (64.5)
2011–16	XVI (243)	175 (72.0)	68 (28.0)	13–95	55.2/55.0 (16.5)	0–150	24.5/21.0 (23.6)	176 (72.4)

SD, standard deviation; LOS, length of stay.

municipalities without cases of hospitalizations for PTB. This observation reflects the growing number of municipalities that do not have notified cases of PTB<sup>7</sup> or have a low number of cases.<sup>30</sup>

Thus, the areas with the higher number of cases of PTB identified in these studies are consistent with the areas we identified with higher number of PTB hospitalizations. Lisboa and Porto are the two main cities in the country, so as observed in other low incidence countries in the EU,<sup>31,32</sup> TB has concentrated in Portugal major cities where homelessness, poverty, migration, substance abuse and other relevant risk factors are common and frequently overlapping in the same urban population groups.

Because TB is considered an ACSC, the access to the primary health care is other factor that influences the hospitalization rates by municipality. Despite the advances, a number of challenges remain to improve the quality of care in Portugal. Although great efforts have been made to improve the access and quality of the primary care network, the country still presents some heterogeneity in terms of response to the needs of the population.<sup>28,33</sup> Portugal still presents an inequitable distribution of healthcare resources, resulting in limited access to health care services for poorer and geographically isolated people resulting in overuse of the emergency care services.<sup>28,33</sup>

When looking at the descriptive analysis, Lisboa and Porto were the municipalities with maximum rates only in 2 of the 15 years studied—Lisboa in 2004 and Porto in 2002. Municipalities with the maximum rates in the descriptive analysis were not completely consistent with the critical areas identified through space–time clustering. We observed that some municipalities with high PTB hospitalization rates had few cases and small populations, producing inconstant variations over time. Because of this, space–time clustering is preferred for identifying critical areas, as it uses appropriate distribution models to deal with small numbers and fluctuations in the trend of the disease over time and space.<sup>17</sup>

To our knowledge, this study is one of the first spatiotemporal analyses of PTB hospitalizations and the first to be conducted in Portugal, providing a starting point for future studies conducted in this area.

Comparing our results with previous studies concerning the Portuguese population and space–time analysis focused on PTB cases,<sup>7,29</sup> regardless of hospitalization status, we observed some differences. Although we also identified Lisboa and Porto metropolitan regions as critical areas, other regions presented clusters of higher rates of PTB hospitalizations. In the overall analysis (2002–16), in addition to the Lisboa (Cluster I) and Porto (Cluster II) metropolitan regions, three clusters were identified, one at the center/south (Cluster IV), one in the north (V) and one at the northeast (III) region of the country. In 2011–16 analysis, in addition to the Lisboa (Cluster VI) and Porto (Cluster VIII) metropolitan regions, two critical areas were detected, one at the south coast (Cluster IX) region and other in the northeast (VII) region. Interestingly, the critical regions identified through spatiotemporal analysis were not exclusively urban areas, in fact, about half of the clusters are predominantly rural regions (Clusters III, IV, V, VII and IX). Therefore, our spatiotemporal analysis identified several regions beyond the major urban centers where clusters of higher rates of PTB hospitalizations occurred over time. These results highlight the need to understand in more detail the reasons behind the high number of PTB hospitalizations in regions not recognized as critical in terms of PTB. This knowledge will enable health policy strategies to be developed to reduce the number of potential avoidable hospitalizations due to TB and strengthen the primary health care systems.

Regarding the 2002–16 period, there was a mean annual percentage change in rate of −7.2%, however when we look at the more recent period (2011–16) we can note a higher mean annual percentage change (−8.12%). This means that in recent years occurred an even better evolution in terms of the incidence of PTB

hospitalizations, whether because of TB control policies implemented, better management of patient care in ambulatory settings or both.

However, despite this trend in the PTB hospitalizations rate, the median LOS remained relatively constant over the 15 years studied (min = 14.0; max = 17.0). Based on cost-effectiveness concerns and to reduce the risk of nosocomial transmission of TB to other patients and healthcare workers, the WHO recommends minimizing unnecessary hospitalization of TB cases by promoting ambulatory diagnosis and treatment.<sup>34–36</sup> Hence, reducing the period of hospitalization should be a priority in the control of the TB epidemic, through implementation of community-based treatment, supported by infection control measures at home, since it was established that treatment success and loss to follow-up improved with outpatient care vs. inpatient care.<sup>37</sup> Also, the risk of death and treatment failure presented minimal difference between patients withstanding outpatient care or inpatient care.<sup>37</sup> Knowing that PTB is an ACSC,<sup>9,10</sup> a reduction in the number of hospitalizations also reflects the implementation of strategies in ambulatory setting that effectively promote timely and effective care thus preventing unnecessary hospitalizations. Nevertheless, more studies should be carried out to better understand the factors that contribute to the relatively constant median LOS through the years, despite the reduction in PTB hospitalization rates observed between 2002 and 2016. These studies should help understand if the median LOS is being influenced by the most severe cases of PTB or are there other factors that could be attenuated or altogether removed to reduce the LOS.

With the exception of cluster XIV (+4.34%) all identified clusters in 2002–16 time period presented a decreasing trend of PTB hospitalizations, even though the decreasing trends were considerably lower than the country trend. Urban regions presented a lower decreasing trend than rural regions possibly because in urban areas there are higher number of risk factors, such as drug dependence or HIV infection, which can lead to more severe cases of PTB and consequently higher likelihood of hospitalization.

Observing the reduction in the number of clusters between the overall period and the recent period suggests that the strategies implemented to control the TB epidemic are going in the right direction.

However, the spatial variation in temporal trends in the 2011–16 period, as identified a single cluster (Cluster XVI) that presents an increasing trend of PTB hospitalizations (+9.5%), a tendency contrary to the trend of country for the same period.

Therefore, the use of spatiotemporal analysis made it possible to identify a geographical area that may need closer observation to understand which factors are contributing to the increase in the number of hospitalizations to reverse this trend.

Several studies have been conducted using spatial and temporal cluster analysis applied to TB control, in countries such as Brazil,<sup>38</sup> China<sup>19</sup> or Spain,<sup>39</sup> and the results are in line with what we observed in our study. That spatial and temporal cluster analysis applied to TB control and elimination can help to estimate periods and geographic areas at risk and provides useful information for the development of health policies.

Furthermore, the implementation of the End TB Strategy, the global strategy endorsed by the WHO to control and ultimately eliminate the TB epidemic, should involve a comprehensive epidemiological assessment based on available data with the objective of understanding the distribution of the burden of disease and identify geographical areas (urban and rural) with high TB burden.<sup>40</sup> Space–time analysis can identify high-risk periods and high-risk areas, thus helping to develop interventions that are likely to have greater effectiveness and higher impact.

## Conclusions

Globally, high TB hospitalizations rates are aligned with high TB notified rates, but other important factors can interact in this relation, namely differences in primary health care services and differences in patient profiles (sociodemographic characteristics and clinical complexity). Further studies, based on more comprehensive information, should be developed.

The two major cities in the country (Lisboa and Porto) presented the highest number of episodes of PTB hospitalizations and the highest rates of PTB hospitalizations, in the period from 2002 to 2016.

In our study, we identified a region in the northeast of the country that in the last 6 years presented a positive trend of PTB hospitalizations (+9.53%), opposite to that of the country (−8.12%). This region should be studied more closely to establish the causes that led to this upward trend in PTB admissions so that health services develop appropriate strategies to reverse this trend.

Spatial and temporal cluster analysis constitute complementary tools for epidemiological surveillance of infectious diseases such as TB, helping in the decision making process and the implementation of specific public health interventions and health policies.

## Supplementary data

Supplementary data are available at *EURPUB* online.

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*Conflicts of interest:* None declared.

## Key points

- Spatial and spatiotemporal analysis can help identify areas with relevant epidemiological phenomena, thus constituting an important resource in terms of public health knowledge and support local strategic interventions.
- The application of this approach to TB hospitalizations has not been sufficiently explored, but could be a valuable aid in implementing or improving health care strategies, as TB hospitalizations can reflect the evolution of the disease in the community.
- With this study, through describing how critical incidence areas evolve and characterizing distinct regional time trends, we demonstrate that knowing the spatial and temporal trends of hospitalizations due to TB can help assessing where health care policies for disease prevention and control are successfully implemented or where measures are not having the desired impact and should be more closely studied to develop distinctly adapted control strategies.
- Considering that TB is an ambulatory care-sensitive condition, reinforced by the fact that and TB incidence is decreasing, the identification of critical areas and areas with positive trends is of utmost relevance to support local strategies to improve primary health care to avoid unnecessary hospitalizations for TB

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