Palliative Medicine & Care International Journal
ISSN: 2688-3821

Juniper Publishers
key to the Researchers

Research Article
Volume 1 Issue 4 - January 2019
DOI: 10.19080/PMCIJ.2019.01.555569

Palliat Med Care Int J

Temporal and Spatial Patterns of Tuberculosis Mortality in Ceará

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Submission: December 18, 2018; **Published:** January 18, 2019

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Abstract

Tuberculosis (TB) is an important cause of morbidity and mortality in developing countries, such as Brazil. Although there is a reduction of these indicators, it is still a challenge in public health, also in Ceará, since death can be considered preventable. Areas with high risk of death in the territory are useful information for the planning of health actions and prevention and control measures, including for nurses, within the multidisciplinary team. Thus, the objective was to analyze TB mortality (as a basic and associated cause) and its spatial correlation in Ceará. Sectional study of deaths from tuberculosis recorded in SINAN and SIM, between the years 2005-2014, of people aged 15 years and older who resided in the municipalities of Ceará, in the northeast of Brazil. The time trend of mortality was calculated from the linear regression equation and p-value in the Statistical Package for the Social Sciences (SPSS) version 22.0 software, and the chart from Microsoft Excel 2011. The spatial distribution of mortality by TB had as unit of analysis the municipalities of the State of Ceará, being used the digital mesh in 2010, from the cartographic base of IBGE, and the ArcGIS program version 9.3 for representation on the map.

There was approval by the Research Ethics Committee of the Federal University of Ceará, according to opinion no. 1,292,605/2015. TB was the basic cause of death in half of the cases reported, and as a cause associated with AIDS-related deaths, neoplasms, and chronic diseases of the respiratory and circulatory system. There was a decrease in TB mortality (basic cause or associated cause) between 2005 and 2014, with the identification of four spatial clusters of risk areas for death in the macro-regions of Fortaleza, Sobral and Cariri, which should be a priority for reducing mortality and planning programmatic actions. It is recommended the investigation of all deaths to promote epidemiological and operational reflections on cases that evolve to death and the use of tools for the improvement of health information systems, with completion of information in real time (online), from electronic mobile devices, considering the specificities of the disease, which requires a long-term treatment and transfer between diagnostic and therapeutic services.

Keywords: Mortality; Tuberculosis; Spatial analysis

Abbreviations: TB: Tuberculosis; SINAN: Information System for Accidental Notification; SIM: Mortality Information System; WHO: World Health Organization; ICD-10: International Classification of Diseases; SPSS: Statistical Package for the Social Sciences; SESA: Secretariat of Health of Ceará; SUS: Single Health System; GDP: Gross Domestic Product

Introduction

Tuberculosis (TB) is the most common cause of death from communicable diseases in developing countries, and occurs in areas with poor nutrition, poverty and population agglomeration [1]. Murray et al. [2] state that there are factors that influence death such as demographic aging, alcohol use, diabetes and smoking. Larroque & Santos [3] report that this disease attacks people of productive age, causing impact on the years of life lost and relevance in public health. In 2016, according to the World Health Organization (WHO), 10.4 million people developed TB, with 1.3 million deaths worldwide, being the main silent killer this year [4]. In 2017, there were 69,569 new cases in Brazil, with an incidence of 33.5 cases per 100,000 inhabitants, with a reduction of 1.6% per year from 2008 to 2017 [5]. In Ceará, from 2013 to 2017, 17,378 new cases and 959 deaths were diagnosed and recorded. The incidence decreased from 39.4/100 thousand inhabitants in 2013 to 38.3/100 thousand inhabitants in 2017, which represents a decrease of 1.1% [6].

In Brazil, TB mortality tends to decrease by 2% in the annual average between 2007 and 2016, with an average of 4,426 deaths per year [5]. The mortality coefficient in Ceará fell from 3.4 in 2001 to 2.2/100,000 inhabitants in 2017 [6]. Both in Brazil and in Ceará, there has been a decrease in incidence and mortality, although efforts are still needed to achieve the goals for the end of TB as the public health problem, that is, to reduce the incidence to 10 cases and less than one death per 100 thousand inhabitants by 2035 [5,6]. TB death is considered preventable

and is a sentinel event that may be indicative of failures in health services, as well as a timely event to discover new cases [6].

In this context, it is observed the importance of information systems for the planning of actions, such as the Information System for Accidental Notification (SINAN) for the monitoring of cases reported to epidemiological surveillance and their evolution to deaths, and the Mortality Information System (SIM) that provide important information on deaths [7], to provide a reliable epidemiological framework for the implementation of monitoring strategies [7]. From the use of geoprocessing it is possible to point out critical areas and prioritize actions, including for population groups with higher risk of death, in addition to enabling the association with the characteristics of social space. Regarding TB, it allows associations with demographic and socioeconomic conditions and identification of the occurrence of the disease in the territory [8]. For nursing, mortality is relevant since professionals are directly involved in the active search for cases, adherence to treatment and control of communicants [9]. Considering that TB is related to the social development of a population and the clustering of cases, it is urgent to identify areas with high risk of death in the territory, in order to provide useful information for planning health actions and prevention and control measures, including for nurses. In view of the above, the objective was to analyze tuberculosis mortality as a basic and associated cause, as well as its spatial correlation.

Material and Method

Sectional study of TB deaths registered in SINAN and deaths from TB as a basic or associated cause, registered in the SIM, between the years 2005-2104, of people aged 15 years and older who resided in the municipalities of Ceará, in northeastern Brazil. All cases confirmed in SINAN by laboratory and/or clinical-epidemiological criteria for epidemiological surveillance purposes were considered as deaths from TB, which evolved to death. The basic or associated cause of death is that coded between A15 and A19 of the 10th revision of the International Classification of Diseases [10], recorded in part I (lines a, b, c, d) or part II of the death declaration entered in the SIM [11,4]. The time trend of mortality was calculated from the linear regression equation and p-value in the Statistical Package for the Social Sciences (SPSS) version 22.0 software, and the chart from Microsoft Excel 2011. Analysis of the spatial distribution of mortality was performed from thematic maps, which had as unit of analysis the municipalities of the State of Ceará, being used the digital mesh in 2010, from the cartographic base of IBGE [12].

Mortality per municipality was stratified into four classes by the quartile method. Then, the indicators were estimated using the local empirical Bayesian method, which made it possible to smooth the random effects resulting from the calculation of indicators for small areas and populations, as well as the annual fluctuations, considering the spatial correlation between neighboring areas, according to Santos & Souza [13] available in the *Terraview* version 4.2.2, public domain program [14]. Microsoft Excel 2011 was used to prepare tables and graphs, and the ArcGIS program version 9.3 for representation on the map of Ceará.

SINAN and SIM data were obtained from the Health Information and Analysis Center of the Health Promotion and Protection Coordination of the Secretariat of Health of Ceará (SESA), with the last update on October 23, 2015. The data on the resident population by municipality were obtained from the 2010 national census of the IBGE, available on the official website of the institution [12]. The research was approved by the Research Ethics Committee of the Federal University of Ceará, according to opinion n. 1,292,605/2015. It was not necessary to obtain the informed consent form, as these were secondary cases.

Results

Table 1: Deaths by TB (as a basic cause) and by other basic causes (when TB was associated cause) recorded in SINAN and SIM by closure criterion, Ceará, 2005 to 2014.

Criterios de encerramento	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Obito por TB	262	290	306	345	349	301	268	250	238	197	2806
Obito por owns causas	337	296	262	260	291	295	312	284	264	157	2758
Total	599	586	568	605	640	596	580	534	502	354	5564

Source: Prepared by the author, 2018

Mortality as a basic cause of death was 3.1 deaths per 100,000 inhabitants in 2005, with annual oscillations, being the highest mortality in 2008 and 2009, with decrease after 2010, reaching 2.3 deaths/100,000 inhabitants in 2014 in Ceará. Mortality from other basic causes (in which TB was an associated cause) was 4 deaths per 100,000 inhabitants in 2005, with a decrease to 1.9 deaths per 100,000 inhabitants in 2014. (Chart 1). It should be noted that in 2014 there was a lower number of deaths than expected, which may be justified by a delay in closing cases, or in entering data into the information systems used (SINAN and SIM). TB-related deaths as a basic and associated cause decreased from 599 deaths in 2005 to 354 deaths in 2014. TB was the basic cause in 2,806 deaths (50.4%) and was associated cause in 2,758 deaths (49.6%), as described in Table 1.

TB was associated as a cause of death in 337 deaths in 2005 (57%), with a decrease in deaths over the years, and in 2014 there were 157 deaths (45%) in which TB was associated as a cause of death with other basic causes as shown in Table 1. Of the 2,758 deaths in which TB was associated with death, the most mentioned basic causes were from chapter 1 of ICD-10:

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some infectious and parasitic diseases (27.2%), followed by neoplasms, respiratory and circulatory system diseases, external causes and poorly defined causes of death, among others (Table 2).

Table 2: Basic causes when TB was an associated cause (2,758 deaths), recorded in SINAN and SIM by closure criterion, Ceará, 2005 to 2014.

Camas basicas de obito	n	%
Algumas doencas infecaosas e parasitanas	751	27,2
Doenca pelo virus da imunodeficiencia humana (HIV)	633	
sequcla de tuberculose	68	
Septicemia	22	
Outras doencas infecciosas e parasitdrias	28	
Ncoplasias e tumores	327	11,9
Neoplasia branquios e pulmees	116	
Outras neoplasias	211	
Docnca.s do aparelho circulatdrio	221	8
Doencas do aparelho respiratorio	223	8,1
Causas extemas	147	5,3
Doencas do aparelho digestivo	91	3,3
Causas mat definidas	85	3,1
Doenca.s Endocrinas	61	2,2
Outras causal	852	30,9
Total	3	100,0

Source: Research data, 2015.

Among infectious and parasitic diseases, acquired immunodeficiency syndrome (AIDS) was the basic cause in 633 of the 751 deaths (84%). Other basic causes of death were sequelae, septicemia and other infectious diseases such as gastroenteritis, erysipelas, viral hepatitis and leishmaniasis (Table 2). Neoplasms were basic causes in 327 deaths (11.9%), with emphasis on bronchial and lung neoplasms, as well as other neoplasms such as those of the larynx, esophagus, stomach, prostate and non-Hodgkin's lymphoma. Respiratory system diseases were basic causes in 223 deaths (8.1%), with emphasis on pneumonia, chronic obstructive pulmonary diseases and respiratory failure. Circulatory system diseases were a basic cause in 221 deaths (8%), with hypertension, acute myocardial infarction, stroke and heart failure (Table 2). External causes were basic causes in 147 deaths (5.3%) in which TB was an associated cause, with transits accidents, self-harm and gun assaults. Poorly defined causes occurred as the basic cause in 85 deaths (3.1%) in which TB was an associated cause, with "death without medical assistance" mentioned in 32 deaths and the others with poorly defined unspecified causes (Table 2).

Other basic causes occurred in 852 deaths (30.9%) related to mental disorders, blood and hematopoietic organs diseases, central nervous system diseases, skin and subcutaneous tissue, osteomuscular and connective tissue, genitourinary and infectious and parasitic maternal diseases that complicate pregnancy, delivery and puerperium, in which TB was associated cause of death (Table 2). The smoothed mortality rate varied from 0.5 to 5.4 deaths/100,000 inhabitants. The cutoff point is the average mortality rate in Ceará of 3.3 deaths/100,000 inhabitants in the period. The Healthcare region of Fortaleza had a high risk of death from TB in all its municipalities, the highest being in the municipalities of Eusébio (5.4 deaths/100,000 inhabitants), Itaitinga (5.3 deaths/100,000 inhabitants), Fortaleza (5.2 deaths/100,000 inhabitants) and Aquiraz (5.2 deaths/100,000 inhabitants), according to Figure 1.

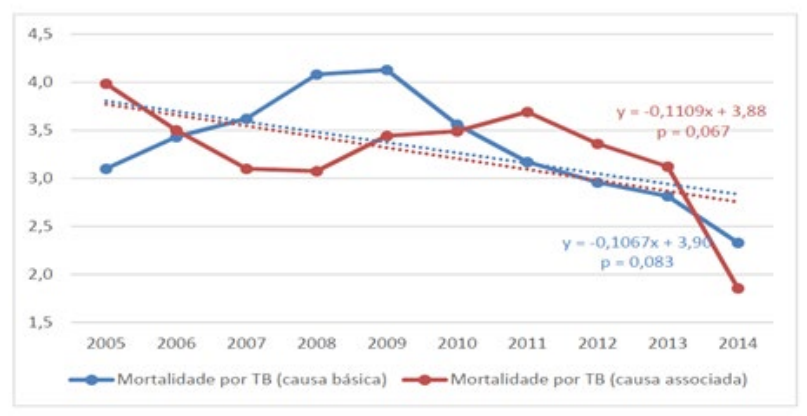

Figure 1: Mortality from TB (as a basic cause) and from other basic causes (when TB was associated cause) in cases registered in SINAN and SIM, Ceará, 2005 to 2014.
Source: Prepared by the author, 2018.

The health region of Maracanaú had a high risk of death in three of the eight municipalities, namely Maracanaú (5.2 deaths/100,000 inhabitants), Pacatuba (4.4 deaths/100,000 inhabitants) and Maranguape (4.1 deaths/100,000 inhabitants). The Caucaia Health region presented two municipalities with high mortality rates among the ten in this region: the municipalities of Caucaia with 5.2 deaths/100,000 inhabitants and Pentecost with 3.5 deaths/100,000 inhabitants. The only municipality in the Cascavel region with high mortality rates was the municipality of Pacajus with 3.8 deaths/100,000

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inhabitants (Figure 1). The region of Saúde de Sobral also showed a concentration of municipalities with a high risk of death, in which ten of the 24 municipalities in this region presented mortality, on average, higher than that of Ceará. The municipality of Sobral had 3.7 deaths/100,000 inhabitants, and nine surrounding municipalities also had high mortality rates such as Meruoca, with 4.2 deaths/100,000 inhabitants, and Coreaú, with 3.5 deaths/100,000 inhabitants (Figure 1). Two municipalities in the health region of Crateús presented high mortality rates, being Ararendá with 4 deaths/100,000 inhabitants and Poranga with 3.4 deaths/100,000 inhabitants. The municipalities in the region of Saúde de Icó that exhibited high mortality were Ipaumirim with 4.2 deaths/100,000 inhabitants, Umari with 3.4 deaths/100,000 inhabitants, and Baixio with 3.7 deaths/100,000 inhabitants, among the seven municipalities of this health region (Figure 2).

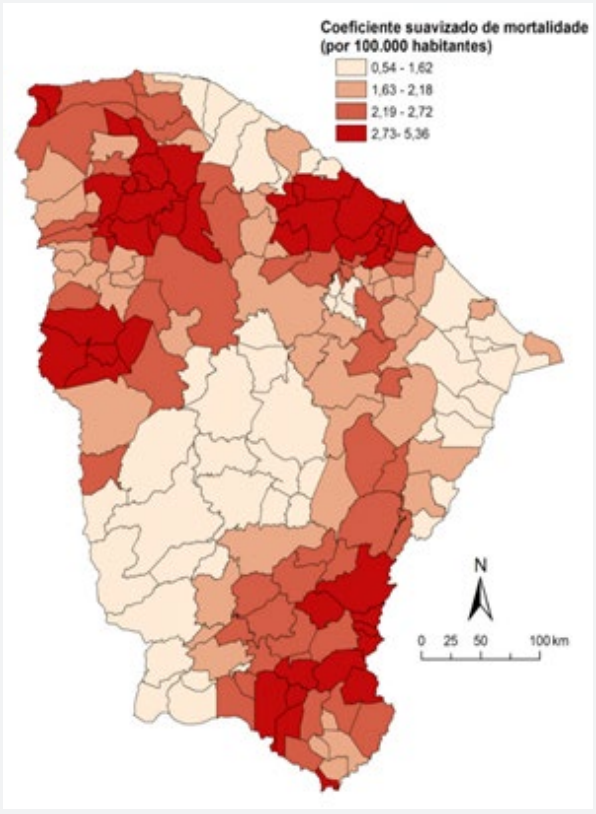

Figure 2: Smoothed mortality coefficient per TB/100,000 inhabitants, on average, according to the municipality of residence, recorded in SINAN and SIM by closing criterion, Ceará, 2005 to 2014.
Source: Research data, 2015.

The Global Moran index was 0.5243 and p-value <0.0001, demonstrating the existence of spatial autocorrelation of the smooth coefficient of mean mortality, globally. The *Moran Map* is the visualization of the Local Moran index that identified spatial *clusters* of death risk areas, according to Figure 3, corroborating findings of conglomerates of municipalities with high mortality, visualized in Figure 1. During the study period, four *clusters* of municipalities at high risk of death (Q1: high-high) were identified in the macro-regions of Fortaleza, Sobral and Cariri. A high-risk death *cluster* covered the municipalities of the health region of Fortaleza (Itaitinga, Euzébio, Fortaleza and Aquiraz), Maracanaú (Pacatuba, Maracanaú, Maranguape and Guaiuba) and the municipality of Caucaia (Figure 3).

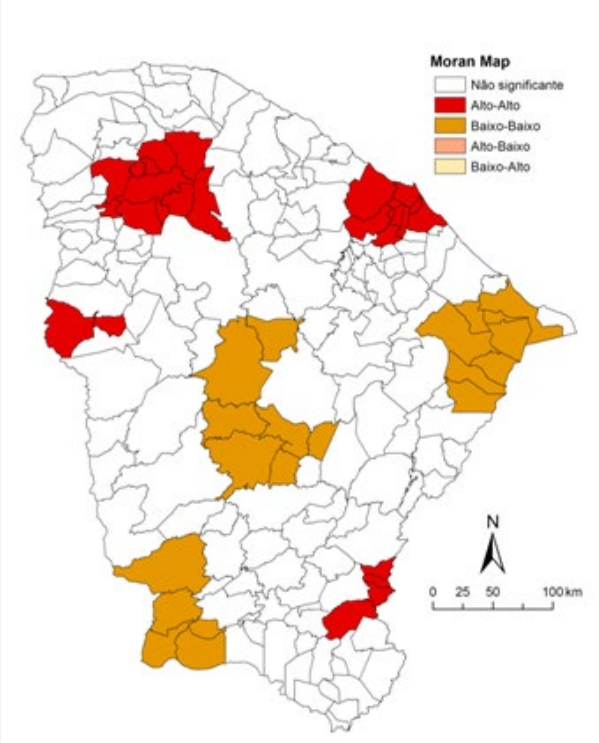

Figure 3: *Moran Map* of the smoothed mortality coefficient per TB/100,000 inhabitants, on average, according to the municipality of residence, recorded in SINAN and SIM by closing criterion, Ceará, 2005 to 2014.
Source: Research data, 2015.

Another *cluster* covered the municipalities of Coreaú, Alcântaras, Meruoca, Massapê, Santana do Acaraú, Forquilha, Sobral, Groaíras, Cariré and Mucambo, in the health region of Sobral. A cluster was identified involving the municipalities of Poranga and Ararendá in the health region of Crateús. And the last *cluster* identified covered the municipalities of Umari, Baixio and Ipaumirim in the health region of Icó and the municipality of Aurora in the health region of Brejo Santo (Figure 2).

Clusters of municipalities with low mortality rates, on average, were located in the health region of Limoeiro do Norte (municipalities of Alto Santo Jaguaribara, Iracema, Potiretama, Pereiro and Ererê), Tauá (Arneiroz, Aiuaba), Iguatú (Catarina and Saboeiro) and the health region of Crato (Antonina do Norte, Campo Sales, Salitre, Araripe, Potegi, Tarrafas, Assaré and Altaneira).

Discussion

The results showed a decrease in TB mortality between 2005 and 2014 in Ceará, which may mean reduced illness and less transmission, or early diagnosis and treatment of

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cases. Another point that may occur is the lack of diagnosis of cases that progress to death, as well as underreporting and underreporting in the death declaration. Deaths can be influenced by several factors, as mentioned above. According to Santos [15], public policies and international organizations are required to make a constant collective effort to change endemic patterns, which translates into a social will to change both the reduction of cases and deaths. TB was the basic cause in half of the deaths during the study period, and in the deaths in which TB was the associated cause, AIDS was highlighted as the basic cause, followed by neoplasms and diseases of the circulatory and respiratory system, and to a lesser extent by external and ill-defined causes, as well as maternal diseases that complicate pregnancy, childbirth and puerperium.

Silva et al. [16] consider as preventable deaths from cases, those who had the disease itself as the main cause of death, since it is assumed that TB has a free treatment and has been available in the public network of the Single Health System (SUS) for half a century. The severity of the cases is related to other comorbidities such as AIDS, diseases of the circulatory system, respiratory system and neoplasms. Alves et al. [17,18] reported that TB presented as an opportunistic disease leading to the occurrence of deaths in AIDS patients. These illnesses can influence the delay in diagnosis or failure to treat/monitor cases. The identification of deaths due to comorbidities and chronic diseases in which TB was an associated cause makes it possible to measure the magnitude of the disease and the higher occurrence of unfavorable outcomes [19]. In some deaths, ill-defined causes of death were recorded, including the mention of "death without medical assistance". Rocha MS et al. [19] report that TB was not recorded as a basic or associated cause in a considerable portion of deaths of patients who were on treatment for TB. The authors emphasize the importance of performing bacteriological tests for TB associated with bronchoscopy and biopsy for proper diagnosis.

Severe TB cases may evolve to death without timely assessment of the history and confirmation of diagnosis, influenced by communication gaps between the hospital network and follow-up in primary care. Poorly defined causes of deaths in patients undergoing TB treatment also point to low investigation and quality of information [19]. A study on preventable TB deaths in Fortaleza, Ceará, talked about the severity of the disease and how it is still neglected. Death is an unfavorable outcome that indicates the need to improve work processes in health services, in addition to intersectoral policies and actions to reduce poverty and social inequalities [20]. In relation to TB mortality, this is an indicator used to monitor control actions from deaths as a basic cause of TB in the SIM. This indicator does not consider TB as a cause associated with death, in which another basic cause occurs, such as AIDS, neoplasms and chronic degenerative diseases [19]. Thus, four clusters with high risk of death from TB were identified: the first involving Fortaleza and eight municipalities in the metropolitan region (Itaitinga, Eusébio, Aquiraz, Pacatuba, Maracanaú, Maranguape, Guaiuba, Caucaia). These municipalities are constituted by an important population agglomeration, with great political and economic expression, due to the concentration of industrial hubs in the municipalities along the BR- 116 and port complex of Pecém [21].

The results reflect that the state capital and metropolitan region are important spaces with determinants of TB deaths. The fact is that the metropolitan region of Fortaleza has been undergoing rapid transformations and corresponds to the fifth largest in Brazil, with socio-spatial disparities resulting from the productive restructuring process, based on private investments in agribusiness, industry and tourism, stimulating competitiveness between cities to the detriment of development and inter-municipal cooperation [21].

Corroborating, Ceccon et al. [22] report that the risk of death from TB rises substantially when there are inequality scenarios, spaces where there is migration and also few services offered to the population. In this process, the lack of urban planning and management hinders access to urban infrastructure and social/health facilities, associated with poorer housing conditions, flows of people and goods, increasing social and environmental vulnerabilities. Thus, in the metropolitan region of Fortaleza there are areas with large housing estates, larger slums close to industrial areas, as well as precarious housing conditions in communities along rivers and lagoons, with people inserted in the informal labor market [21].

The city of Fortaleza is located on the northern coast of Ceará, being limited to Caucaia, Eusébio, Aquiraz, Maracanaú, Pacatuba, Itaitinga, with a population of more than two million inhabitants in 2010, and demographic density of 7,786 inhabitants/km^2, being the city with the best Human Development Index in the state. It has 5% of its population with monthly per capita household income of up to R$70.00 and concentrates 305 health establishments, in addition to industries, schools and universities [23].

The second high-risk *cluster* for TB deaths involved the municipality of Sobral and nine municipalities in the same health region. The Netherlands (2011, p.100) reported that the municipality of Sobral has undergone changes through economic, political and social restructuring since 1996, attracting investments in the sectors of trade, services and industry, a fact that favored a contingent of neighboring immigrants who seek better prospects for life due to the higher degree of urbanization, and access to health services and health care.

Pedro et al. [24] report that the immigration of people is a challenge for the control of the disease, since agglomerations of people live in places with worse housing conditions and little public services, resulting in illness, thus contributing to the development of TB. In his work, Filho et al. [18] reinforces the previous comment, when he says that the WHO reported that TB is influenced by several social determinants, among others, social

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inequality and migration between regions. The municipality of Sobral belongs to the northwestern mesoregion of Ceará, with a population of 188,000 inhabitants and a population density of 88 inhabitants/km^2 in 2010, and an urbanization rate of 88%. It is the richest municipality, concentrating 89% of the gross domestic product (GDP) of the microregion, although it has 11% of its population with monthly per capita household income of up to R$70.00 [23].

It is the second most developed municipality in the state, according to indicators of health, education, quality of life and GDP per capita. At Sobral's industrial hub there are industries manufacturing footwear, cosmetics, cement, mining, soft drinks, etc. In the health area, there are ten hospitals that serve the population of the northern region, with two doctors for every 1,000 inhabitants, in a total of 91 health units [23]. The third high-risk cluster for TB was identified in the municipalities of Ararendá and Poranga, in the health region of Crateús. Ararendá presented in 2010 an urbanization rate of 46%, population of 10,000 inhabitants, demographic density of 30 inhabitants/km^2, 154th place in the HDI ranking, 38% of its population with monthly per capita household income of up to R$70.00, with six health units in the city. Poranga demonstrated 64% urbanization, population of 12 thousand inhabitants, demographic density of 9 inhabitants/km^2, 164th in the HDI ranking, 37% of its population with monthly per capita household income of up to R$70.00 with nine health units in 2010 [23].

These municipalities are sparsely populated, with low population density and small urbanization, low human development indicators, almost half the population with low income and few health services for diagnosis and treatment. The last high-risk cluster for TB deaths involved the municipalities of Umirim, Baixio, Ipaumirim, in the health region of Icó, as well as the municipality of Aurora, in the health region of Brejo Santo. Ipaumirim presented an urbanization rate of 59%, population of 12 thousand inhabitants, demographic density of 43 inhabitants/km^2, 112th in the HDI ranking, 24% of its population with monthly per capita household income of up to R$70.00, and five health units in the city in 2010. Baixio demonstrated 54% urbanization, population of 6 thousand inhabitants, demographic density of 41 inhabitants/km^2, 55th in the HDI ranking, 21% of its population with monthly per capita household income of up to R$70.00 with only three health units in 2010 [23].

The city of Umirim presented an urbanization rate of 58%, with a population of 18 thousand inhabitants and demographic density of 59 inhabitants/km^2, 156th in the HDI ranking, 33% of its population with monthly per capita household income of up to R$70.00, and twelve health units in the city in 2010. And the municipality of Aurora, in the same year, had 24,000 inhabitants, 48% urbanization rate, 27 inhabitants/km^2, 27% of its population with monthly per capita household income of up to R$70.00 and 18 health units in the municipality [23,25]. These municipalities have the same characteristics as the municipalities with high risk of death from TB in the Health region of Crateús.

Thus, high risk of death from TB may be related to low socioeconomic conditions, socio-spatial disparities and lack of diagnostic and therapeutic structure, as well as to the effect of deaths in small populations, bringing reflections from space in the social dimensions, in which the spread of TB and the historical, environmental and social conditions are related to the individual and collective dimension [19].

Conclusions

TB was the basic cause of death in half of the cases reported, and as a cause associated with AIDS, neoplasms, chronic diseases of the respiratory and circulatory system, demonstrating its magnitude in public health. There was a decrease in TB deaths (basic cause or associated cause) between the years 2005 and 2014 in Ceará, although it is still high compared to Brazil. The spatial analysis showed a high concentration of municipalities with high risk of death in the health regions of Fortaleza, Maracanaú, Caucaia, Sobral, Crateús, Icó and Brejo Santo. Four spatial clusters of TB risk areas were identified in the macro-regions of Fortaleza, Sobral and Cariri. Thus, showing that these geographic areas should be priorities for reducing TB mortality in Ceará, as well as for planning and monitoring TB programmatic actions.

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DOI: 10.19080/PMCIJ.2019.01.555569

How to cite this article: Dalila A P; Monica C F, Antônio B V J. Temporal and Spatial Patterns of Tuberculosis Mortality in Ceará. Palliat Med Care Int J. 2019; 1(4): 555569. DOI: 10.19080/PMCIJ.2019.01.555569