REVISTA DO INSTITUTO DE MEDICINA TROPICAL DE SÃO PAULO

JOURNAL OF THE SÃO PAULO INSTITUTE OF TROPICAL MEDICINE

ORIGINAL ARTICLE

http://doi.org/10.1590/S1678-9946201961068

Spatial analysis of leishmaniasis in Brazil: a systematized review

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ABSTRACT

The aim of this study was to perform a systematic review of scientific papers that used spatial analysis tools in cases of leishmaniasis, in Brazil. The search for articles was carried out in PubMed, SciELO, Scopus and Web of Science databases. The keywords used in the identification of the articles were Thematic map AND Leishmaniasis, Spatial analysis AND Leishmaniasis, and Geoprocessing AND Leishmaniasis, in English language. A total of 360 articles were found, and 11 of them were analyzed after screening by title and abstract as well as reading of the full articles. The States studied were Sao Paulo, Acre, Maranhao, Piaui, Minas Gerais, Parana and Tocantins. Cutaneous leishmaniasis occurred predominantly in rural areas, with clusters in forest reserve regions or modified forest areas. Conversely, visceral leishmaniasis mainly occurred in peripheral and central urban areas associated with poorer environments and urban infrastructure, including worse sanitation. We conclude that the spatial distribution of leishmaniasis is closely related to the living environment of the risk population. The analyzed articles associated geospatial data with some risk factors for the disease, pointing out the locations where most cases occur, creating a relevant source to define control strategies.

KEYWORDS: Geoprocessing. *Leishmania.* Risk factors. Zoonosis. Spatial analysis.

INTRODUCTION

Leishmaniasis is a globally distributed disease. Approximately 350 million people are at risk of contracting at least one of its forms[1]. Brazil has an annual average of 26,965 cases of cutaneous leishmaniasis (CL) recorded from 1993 to 2012, with an average detection coefficient of 15.7 cases per 100,000 inhabitants[2]. Visceral leishmaniasis (VL) is one of the most severe public health problems in several countries in the Americas and is a constant challenge for public health in Brazil[3].

Leishmaniasis is a complex of zoonotic diseases transmitted by sand flies of the genus *Lutzomyia* and has as reservoir several species of wild and domestic animals. The environment plays an important role in the cycle of disease transmission, as it is responsible for vector maintenance[4].

Knowledge regarding spatial patterns of disease by means of geoprocessing techniques is important for proper orientation of prevention, surveillance and control measures, making it possible to monitor territorial units of epidemiological significance and serving as a tool for reliable decision-making[2,5].

Systematic review studies are an important tool for analyzing research in a given area of knowledge, favoring the access of researchers to strategic information[6]. The aim of this study was to perform a systematic review of papers that used spatial

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Received: 7 June 2019

Accepted: 25 October 2019

analysis tools to analyze cases of human leishmaniasis in Brazil.

MATERIALS AND METHODS

We searched the PubMed, SciELO, Scopus and Web of Science databases on August 27 and 28, 2017. The keywords used were *Thematic map* AND *Leishmaniasis*, *Spatial analysis* AND *Leishmaniasis* and *Geoprocessing* AND *Leishmaniasis*, only in English language.

The inclusion criteria were studies written in English and Portuguese that used spatial analysis to analyze environmental risk factors in cases of CL and VL in humans. Exclusion criteria were review articles, studies with non-human infecting species studies on diagnostic methods and studies performed outside Brazil.

Once the database queries had been concluded, the Mendeley® software was used to analyze the file libraries generated by each database excluding duplicates, as well as empty files and others obtained after filtering by title and abstract. Three researchers selected titles and abstracts based on the criteria presented above.

RESULTS

We identified a total of 360 articles in the PubMed, SciELO, Scopus and Web of Science databases, with 146, 61, 15 and 138 articles for each database, respectively. After title screening, 125 abstracts were read and analyzed, of which 27 were selected for reading of the full texts. Of these, four articles were excluded because the authors did not perform spatial data analysis, and in other 12 articles, the authors did not correlate leishmaniases with environmental aspects (Figure 1). An article published after the searching stage had been completed was included, as it was considered of great relevance to this study.

Regarding the database used in each paper, ten studies used the System of Notification Diseases (SINAN) of the Brazilian Ministry of Health (MS) as a source of data collection in different periods between 1992 and 2015. However, Machado-Coelho *et al.*[7] evaluated cases from 1966 to 1996 using the passive surveillance system specific to leishmaniasis as a database. This surveillance system used clinical diagnoses confirmed by the Montenegro test and/or parasitological examination.

Cutaneous Leishmaniasis

Three of the five included CL studies assessed incidences in urban and rural areas. Machado-Coelho *et al.*[7] analyzed 1,712 cases in 12 districts of Caratinga, Minas Gerais State, from 1966 to 1996. The authors stated that 77% of the cases in 10 districts took place in rural areas. However, in the Municipality of Caratinga and the districts of Ipaba and Santa Rita 77.1%, 50% and 65% of the CL cases, respectively, occurred in urban areas. Nasser *et al.*[8] studied 60 cases reported between 1992 and 2003 in Campinas, Sao Paulo State, where the highest concentration of cases was in the rural area bordering the urban area.

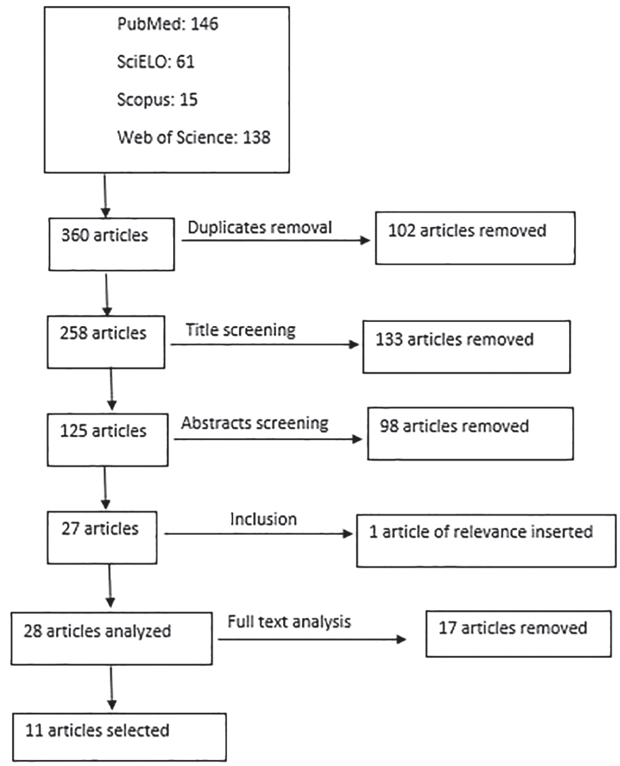

Figure 1 – Flowchart of the articles selection process.

Melchior *et al.*[9] evaluated the prevalence of CL in Acre State from 2007 to 2013 and reported 12.4 cases per 10,000 inhabitants. The highest incidence occurred in rural areas in most of the microregions studied, such as Brasileia (83.2%), Cruzeiro do Sul (71.3%), Tarauaca (70.9%) and Sena Madureira (70%). The only exception was the Rio Branco microregion, in which 50% of the cases occurred in rural areas.

Neto *et al.*[10] analyzed 13,818 cases from 2000 to 2009 along a transcontinental railroad in Maranhao State and found clusters of CL cases and a high risk of CL, influenced by the Amazon forest, along the railway line II located in the Western region of the State.

Melo *et al.*[11] evaluated 4,557 cases of CL reported in Parana State from 2001 to 2015 and observed, through cluster analysis, that there was a spatial correlation with CL along the Ivai river basin from 2002 to 2015. Other rivers had spatial correlations with CL in some years of the study, including Pirapo and Tibagi. Cities with the highest absolute

Table 1 – Characteristics of the spatial analysis of leishmaniasis cases studies in Brazil.

Reference	Aim	Coverage and geographical range analysis	Software	Spatial statistics
Machado-Coelho *et al.*[7]	Estimated the incidence rate of ACL from 1966 to 1996; tested spatial and temporal space patterns on incidence and correlated data with sociogeographic factors.	Caratinga municipality, Minas Gerais State Census sector	Not informed	Moran Index Test, KnoxTest, Poisson Regression Analysis
Nasser *et al.*[8]	Analyzed the spatial distribution and epidemiological pattern of ACL in Campinas, SP, from 1992 to 2003.	Campinas municipality, Sao Paulo State Municipality	Spring 4.01 Beta	Kernel Intensity Estimator
Almeida *et al.*[17]	Identified areas of higher risk of VL in the urban area of Teresina, Piaui State, from 2001 to 2006.	Teresina municipality, Piaui State Census sector	TerraView 3.2.0	Moran test to determine spatial correlation of cases, Kernel test to determine the central areas
Souza *et al.*[12]	Described the occurrence of VL in the municipality of Bauru, Sao Paulo State, between 2003 and 2008 and identified clusters of spatiotemporal diseases to improve knowledge on the disease in this region.	Bauru municipality, Sao Paulo State Census sector	SaTScan v. 8.0	Not informed
Neto *et al.*[10]	Evaluated the temporal distribution of ACL in municipalities located along the road and rail corridor in Maranhao State.	Road and railway corridor, Maranhao State Municipality	WinBUGS software	Bayesian regression model spatiotemporal Poisson
Vieira *et al.*[13]	Described temporal and spatial occurrences of VL in the Municipality of , Sao Paulo State, and identified spatial clusters in highest risk areas for disease occurrence.	Birigui municipality, Sao Paulo State Census sector	SaTScan 9.1.1 software	Poisson model to define spatiotemporal clusters
Cardim *et al.*[14]	Described the spatial occurrence and spatiotemporal cluster of VL in Adamantina, Minas Gerais State; identified and characterized the risk areas for the occurrence of autochthonous cases.	Adamantina municipality, Sao Paulo State Census sector	ArcGIS 10.0	Kernel estimation was used to evaluate the density of cases
Cardim *et al.*[15]	Described the occurrence of VL in humans in space and space-time inSao Paulo State , from 1999 to 2013.	316 municipalities from ao Paulo State Municipality	Not informed	Kernel
Toledo *et al.*[16]	Analyzed determinants for the occurrence of human visceral leishmaniasis associated to vulnerability conditions.	Araguaina municipality, Tocantins State Census sector	ArcGis 10.2	Kernel estimation was used to evaluate the density of VL cases
Melchior *et al.*[9]	Identified the high and low risks of ACL agglomeration in space and space-time in the period from 2007 to 2013, in the municipalities of Acre State.	Acre State Municipality	SaTScanTM	Kulldorffscan statistic was used to evaluate the spatial agglomeration and the probability of Poisson distribution
Melo *et al.*[11]	Used spatial statistics in Parana State to evaluate the dynamics of the occurrence of ACL from 2001 to 2015.	Parana State Municipality	R	Moran Global Index test to detect spatial autocorrelation

number of cases during the study period were Londrina (341) and Cianorte (331).

Regarding the geographic scale of analysis in studies on CL, only Machado-Coelho *et al*.[7] used information at the census sector level, including population density in the census and residence area, presence of basic sanitation and the existence of exposed garbage as covariates in their study. Melchior *et al*.[9] did not perform analysis at the census sector level and considered this characteristic as a limitation of their study.

Visceral Leishmaniasis

Five of the six papers on VL evaluated the incidence of VL in urban and rural areas. Souza *et al*.[12] reported 239 autochthonous cases from 2003 to 2008 in the city of Bauru, SP, all of them from the urban area. Vieira *et al*.[13] analyzed 156 cases of VL reported in the city of Birigui, Sao Paulo State where 87 (55.8%) cases occurred in the urban area. According to the authors, the first reported cases were found in the central region of the municipality and areas with spatial correlation had fruit trees, dogs, chickens and horses near some residences.

Cardim *et al*.[14] analyzed 83 cases of VL reported in Adamantina from 2004 to 2011 and 81 (97.6%) occurred in urban areas. However, a spatial correlation occurred only in 2005 and 2006. In the study of Cardim *et al.*[15], 2,324 cases of VL were reported in 80 municipalities in the Sao Paulo State from 1999 to 2013, with 97.4% of the cases occurring in urban areas.

Toledo *et al*.[16] studied 1,096 cases of VL reported in Araguaina, a city in Tocantins State, from 2007 to 2012 and observed a large cluster in the central urban area and other smaller clusters in the peripheral areas.

Almeida *et al*.[17] studied VL cases in Teresina, Piaui from 2001 to 2006 and reported positive spatial correlations between cases and socioeconomic indicators, such as illiteracy and poorer basic infrastructure conditions. In addition, city peripheral regions presented a higher risk of VL, as observed by kernel mapping, with a greater concentration of VL cases in 2003. Most central areas from the city census sectors did not present significant spatial autocorrelation or a pattern of low incidence rate grouping (low-low).

In Bauru, Sao Paulo State, from 2003 to 2008, the positive seasonal index of VL obtained from the time series model and the average monthly precipitation was higher in rainy periods, from November to January. Cluster analysis of spatio-temporal disease concentration in 2006 in 70 census tracts recorded the highest number of cases on the Southeastern side of the city[12].

The geographic analysis scale used in most selected VL studies was the census sector, and only Cardim *et al*.[15] conducted an analysis based only on municipal information. The covariates from the census-sector level used by Souza *et al*.[12], Vieira *et al*.[13], and Cardim *et al*.[14] were population density, age and sex. Almeida *et al*.[17] used illiteracy rate, percentage of children under the age of five, average per capita income, and presence of basic sanitation, such as tap water, sewage and garbage collection, as covariates at the census sector level. Toledo *et al*.[16] constructed a vulnerability index based on sociodemographic characteristics of census sectors, but performed the final data analysis at the municipal level since georeferencing of the cases was performed only at the neighborhood level.

DISCUSSION

Studies that used spatial analysis as a tool are relatively new as more than 90% of the analyzed articles are from the past nine years. Although few health studies conducted in Brazil used this tool, spatial analysis has relevantly contributed to a better understanding of disease epidemiology, leading more researchers to use spatial analysis as a tool in their studies.

Even with the advantages of the spatial analysis technique, investigations are in general performed with secondary data, leading to ecological studies that may present biases[6]. All the papers evaluated in this review used secondary data. It is well known that an important bias that occurs in this type of study is underreporting, potentially due to misdiagnosis, inadequate medical records, failure of the sick person to seek medical attention or even the deficiency of the local surveillance system[8,17].

The georeferencing methodology of the studies used different softwares but performed very similar spatial distribution analyses. Most of the analyzed articles made an association between spatial data and socioeconomic characteristics; the census sector was used as the level of aggregation in six of the twelve selected papers (54.5%). The use of the census sector as the analysis level together with the sociodemographic data generated by the national census carried out by the Brazilian Institute of Geography and Statistics (IBGE), allowed more accurate results and more effective targeting of prevention actions.

For Machado-Coelho *et al*.[7], the cases of CL clustered in urban areas could lead to four explanations: urbanization of rural areas which are endemic to the disease; variation of sand flies (vectors) habits; number of reservoir animals and variation in the number of susceptible individuals. In rural areas, the exposure of humans to the natural environment is an important factor for disease maintenance.

Most CL cases in Parana State occurred in municipalities in which agriculture is the main economic activity, there was a relationship with leisure activities, such as outdoor trails and fishing, and also with the presence of streams in forests where the enzootic cycle is maintained[11]. The same was observed in Acre State, where forest fragments covering the State contributed to the maintenance of the disease and its high incidence rate in some localities, especially among rubber tappers, riverine population and fishermen[9].

The spatial correlation along the Ivai and Pirapo rivers in Parana State may be due to the high number of sand flies in native forests around rivers that has been well documented in previous studies[18-20]. Some cities with high spatial correlation, such as Jussara and Cianorte, have areas of residual forest that have been intensely altered, as well as secondary forests[21], which are factors that may have led to the highest number of cases in this region.

In Acre State, the highest spatial correlations occurred in the regions of Brasileia and Sena Madureira, where 570 hectares of the Chico Mendes forest reserve are located. In this same study, Rio Branco, the State capital, presented the highest number of cases but with a low spatial correlation. It is probable that there are places within Rio Branco microregion where transmission is intense, and a study using spatial analysis is necessary to locate these high-risk clusters[9].

In the study conducted by Neto *et al*.[10], the area with the highest incidence of CL was in the Western region of the Maranhao State, which is influenced by the Amazon forest. The climate and vegetation of the forest favor a greater diversity of vector species, reservoirs and etiological agents[22]. Sand flies species in this area are quite diverse, including the following that are found abundantly: *L. whitmani, L. migonei, L. umbratilis* and *L. complexa*[23,24].

Unlike CL, VL occurred more frequently in urban areas. For Vieira *et al*.[13], cases are due to a close relationship between humans, dogs and other domestic animals. When organic matter is present in the backyards of the houses, ideal conditions are created for vector maintenance; in addition, families living in these regions have low socioeconomic status. The combination of these factors characterizes this geographic space as an area of high risk for disease occurrence.

According to Almeida *et al*.[17], it is plausible to assume that the introduction, maintenance and dissemination of VL in Teresina, Piaui State, are linked to environmental conditions typically found in lower socioeconomic areas with poorer urban infrastructure, including worse sanitation. These conditions favor not only the proliferation of vectors and reservoirs, but also the presence of many susceptible individuals, low-income young people who are probably malnourished[17].

Toledo *et al*.[21] observed a centrifugal process of disease dissemination in Araguaina, Tocantins State, characterized by important modifications of the territory, such as disordered expansion of the city, entering the natural habitat of the vector, and the lack of basic infrastructure and basic sanitation, enabling the urbanization of sandfliesand the spread of diseases in the municipality[25].Until the 1970s, VL was an endemic disease typical of rural areas, mainly in the Northeastern region of Brazil. From the mid-1980s, its incidence has increased in urban areas, spreading to other regions[5,26]. Changes in the epidemiological characteristics of this zoonosis, especially the expansion and occurrence in urban areas, are related to migration, environmental changes and other anthropogenic factors[27,28].

Kernel maps to detect areas with a higher risk of leishmaniasis occurrence may be useful to support surveillance and vector control measures. Identifying clusters of higher risk areas can help to define priority neighborhoods for specific interventions[17].

CONCLUSION

In conclusion, leishmaniasis presents patterns of spatial distribution that are closely related to the environment in which the exposed population live. CL occurred predominantly in rural areas, with clusters in forest reserve regions or modified forest areas. VL occurred predominantly in peripheral and central urban areas associated with poorer environments and urban infrastructure, including worse sanitation.

The analyzed articles associated geospatial data with highest intensity of some risk factors for the disease, showing where the cases occurred and creating a relevant source for the definition of control strategies. However, the environmental studied factors should be better explored to increase the effectiveness of surveillance and prevention of this endemic disease.

ACKNOWLEDGMENTS

The authors thank the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES), for funding the study by awarding a graduate scholarship (process Nº 88882.344369/2019-01).

AUTHORS' CONTRIBUTIONS

Melca Niceia Altoé de Marchi was responsible for structuring, developing and writing the manuscript and participated in all stages of the manuscript preparation; Eloiza Teles Caldart and Fellipe Danyel Cardoso Martins carried out the screening of titles and abstracts and helped in writing the manuscript; Roberta Lemos Freire is the senior researcher.

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