Spatial analysis of hospitalizations for pneumonia in the Vale do Paraíba region of Brazil*

Análise espacial das internações por pneumonia na região do Vale do Paraíba (SP)

Adriana de Oliveira Mukai, Kátia de Souza Costa Alves, Luiz Fernando Costa Nascimento

Abstract

Objective: To identify spatial patterns in hospitalizations for pneumonia in infants under one year of age in the Vale do Paraíba region of Brazil. **Methods:** This was an ecological exploratory study using a georeferencing technique based on data from the Information Technology Department of the Brazilian Unified Health Care System on the number of hospitalizations for pneumonia among infants under one year of age in the Vale do Paraíba region between 2004 and 2005. Based on the distribution of the rates of hospitalizations for pneumonia per 1,000 live births, thematic maps were created. Moran's spatial autocorrelation coefficient was estimated, and the cities with the highest rates were identified using box maps. **Results:** During the study period, 2,227 infants under one year of age were hospitalized for pneumonia. Moran's coefficient was 0.37 (p = 0.02), demonstrating a spatial autocorrelation for these hospitalizations. Eight cities deserving special attention for future interventions were identified. **Conclusions:** The spatial analysis was successful in determining the spatial autocorrelation, as well as in identifying the cities in which an intervention is necessary regarding the number of hospitalizations for pneumonia in infants under one year of age.

Keywords: Pneumonia; Geographic information systems; Child health (Public health); Infant.

Resumo

Objetivo: Identificar padrões espaciais nas internações por pneumonia em menores de um ano de idade e identificar os municípios com prioridade para intervenção no Vale do Paraíba (SP). **Métodos:** Estudo ecológico e exploratório utilizando-se de técnica de geoprocessamento com dados do Departamento de Informática do Sistema Único de Saúde sobre o número de internações por pneumonia em menores de um ano de idade no Vale do Paraíba paulista nos anos 2004 e 2005. Foram obtidas taxas por 1.000 nascidos vivos e, a partir das distribuições dessas, foram criados mapas temáticos. Estimou-se o coeficiente de autocorrelação espacial de Moran e identificaram-se os municípios com altas taxas através de *box map*. **Resultados:** No período do estudo, 2.227 crianças com menos de um ano de idade foram internadas por pneumonia. O coeficiente de Moran foi de 0,37 (p = 0,02), o que demonstrou a existência de uma autocorrelação espacial para essas internações. Foram identificados oito municípios que merecem uma atenção especial para possíveis intervenções. **Conclusões:** A análise espacial foi utilizada com sucesso para determinar a autocorrelação espacial e para identificar os municípios onde é necessária uma intervenção em relação ao número de internações por pneumonia em menores de um ano de idade.

Descritores: Pneumonia; Sistemas de informação geográfica; Saúde da criança; Lactente.

* Study carried out in the Department of Internal Medicine of the University of Taubaté, Taubaté, Brazil.
Correspondence to: Luiz Fernando Costa Nascimento. Rua Durval Rocha, 500, Vila Paraíba, CEP 12515-710, Guaratinguetá, SP, Brasil.
Tel 55 12 3625-4271. E-mail: lfcn@unitau.br
Financial support: This study received financial support from the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, Foundation for the Support of Research in the State of São Paulo; grant no. 08/51485-6).
Submitted: 21 January 2009. Accepted, after review: 8 April 2009.

Introduction

Pulmonary infections constitute a major cause of morbidity and mortality among children in developing countries.[1] According to the *Departamento de Informática do Sistema Único de Saúde* (DATASUS, Information Technology Department of the Brazilian Unified Health Care System), approximately 130,000 children under one year of age were hospitalized for pneumonia in Brazil in 2005, approximately 22,000 of those hospitalizations occurring in the state of São Paulo.[2]

Calculated in Brazilian reals (R$), those hospitalizations cost the *Sistema Único de Saúde* (SUS, Unified Health Care System) R$86 million in Brazil as a whole and R$16 million in the state of São Paulo alone.[3] Nationwide and in the state of São Paulo, respectively, there were 2,357 and 418 deaths due to pneumonia,[4] translating to mortality rates of 1.53% and 1.49%, respectively. These numbers do not include children whose hospitalization was covered by private health insurance plans or other by other funding sources.

Among the risk factors for childhood hospitalization due to respiratory diseases are the following: impairment of nutritional status; lack of breastfeeding; low educational level of the parents; low birth weight; close living quarters; smokers in the home; and poor socioeconomic conditions.[5-8] Air pollution is also associated with hospitalization of children for pneumonia.[9]

In recent years, geographic information systems have gained space in epidemiological studies, identifying spatial patterns for different situations, including those related to health and epidemiology, violent deaths, infant mortality and neonatal mortality.[10-13] In this context, one group of authors[14] identified high-risk areas for pneumonia in the city of Goiânia, located in the state of Goiás, Brazil, using the point analysis technique. Technically, spatial analysis can be made through point analysis, in the case of a city or neighborhood, or through analysis by area, in the case of states or regions of the state.

The health care scenarios drawn by the georeferencing techniques aggregate the geographic component of the neighboring relationship between places to the socioeconomic, environmental and structural health care data. Therefore, spatial correlation data characterize regional scenarios, allowing the planning of intervention strategies within the same geographic sphere. In the current political and administrative moment, geared toward the strengthening of the regionalization of SUS, the exploration of data through geographic information systems provides technical aid for the elaboration of regional policies. Therefore, these systems can provide geographic data that allow a regional intervention, which yields better results when compared with a local intervention, as well as allowing the results of the intervention to be judged.

The present study was aimed at using georeferencing techniques in order to identify spatial patterns in hospitalizations for pneumonia in infants under one year of age, as well as to determine which cities should be considered priorities for intervention, in the Vale do Paraíba region of Brazil.

Methods

This was an ecological exploratory study, using georeferencing tools, in the Vale do Paraíba region of Brazil. The data on hospitalizations for pneumonia in infants under one year of age were obtained from the SUS via the DATASUS site. Data related to the Regional Health Department (RHD) of Taubaté, with 35 cities and approximately 2 million inhabitants, were obtained (Figure 1).

We studied the years 2004 and 2005. We chose this option to minimize the chance of errors in the reporting of diagnosed cases of pneumonia, which would result in the underestimation or overestimation of hospitalization rates. For our study, hospitalization rates were calculated per 1,000 live births for the two years grouped.

The spatial analysis used a digital database generated at the University of Taubaté Georeferencing Laboratory, and data were analyzed using the freeware TerraView, version 3.2.0, developed by the Brazilian National Institute for Space Research. The values for the hospitalization rate variable were divided into tertiles; and the rates were classified as low, medium or high.

The indices used in our study to identify the spatial correlation were the global Moran's indicators. The global indicator analyzes whether the data present spatial correlation, that is, whether there are clusters of cities with high rates and

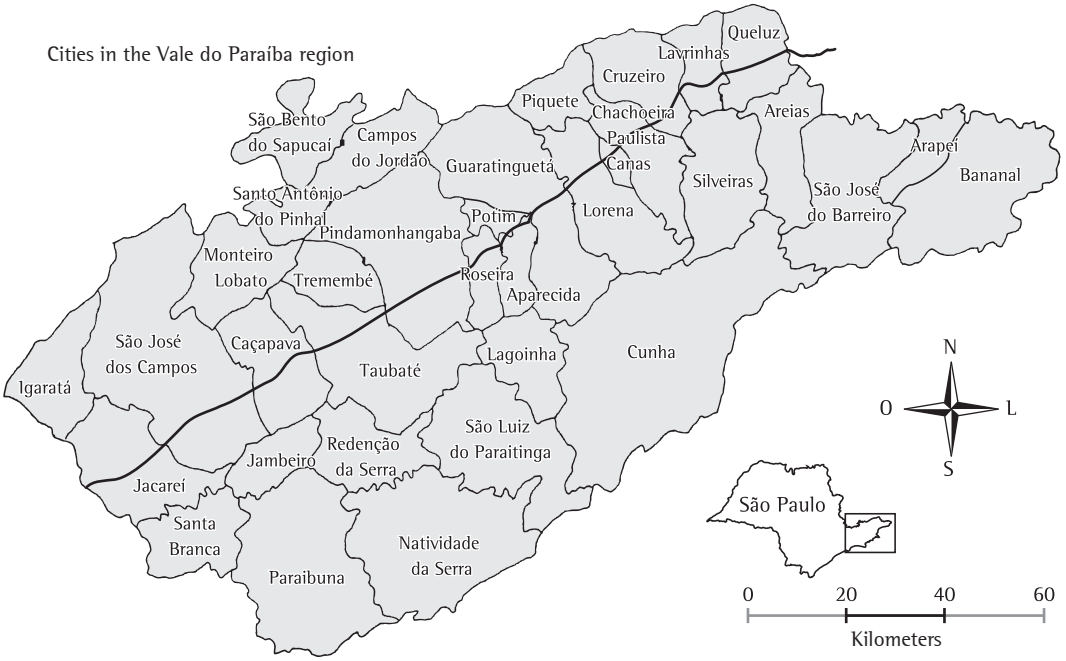

Figure 1 - Cities in the Vale do Paraíba region of Brazil.

clusters with low rates. The Moran's global indicator varies between −1 and +1, and a level of significance can be attributed to it.

Using the diagram devised by Moran, the cities were identified by quadrant, the first quadrant indicating a high priority of intervention due to the high rates of hospitalization for pneumonia and due to the fact that their neighboring cities also presented high rates. The diagram determines the location of each city in one of the following four quadrants: quadrant 1, high-high, in which the city has a high rate of hospitalization for pneumonia and is surrounded by cities with high rates; quadrant 2, low-low, in which the city has a low rate of hospitalization for pneumonia and is surrounded by cities with low rates; quadrant 3, high-low, in which the city has a high rate of hospitalization for pneumonia and is surrounded by cities with low rates; and quadrant 4, low-high, in which the city has a low rate of hospitalization for pneumonia and is surrounded by cities with high rates. Consequently, cities located in quadrant 2 are low priorities for intervention. Cities located in quadrants 3 and 4 represent localities with medium priority for intervention. This distribution is shown using a box map. The box map defines, in the map, the distribution of the cities according to the quadrant to which they belong.

The area of study currently corresponds to the regions Serrana e Circuito da Fé, Alto Vale do Paraíba and Vale Histórico, which constitute, along with the North Shore (not analyzed in this study), the area served by the RHD of Taubaté. The human development index of the cities that constitute this region situates the cities at the two extremes: rich cities, with good social indicators, and poor cities, with precarious social indicators. Although the region has natural identifying landmarks, such as the Paraíba River and the mountain ranges (the Serra da Mantiqueira and the Serra do Mar), it is the Presidente Dutra Highway which marks the distinct social and economic characterization of its cities: the largest and most dynamic centers are located along the highway. This differentiation is also reflected in health care, and the most dynamic cities (especially Taubaté, where the RHD is headquartered, and São José dos Campos) are also where the hospitals and specialized clinics of the region are concentrated. Pediatric hospitalizations were concentrated in three circuits, which are delineated by the cities of São José dos Campos, Campos do Jordão, Guaratinguetá, Pindamonhangaba, Taubaté and Cruzeiro.

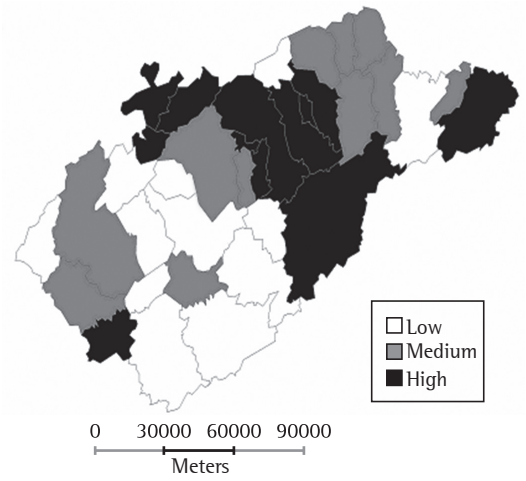

Figure 2 - Rates of hospitalization for pneumonia, per 1,000 live births, in the Vale do Paraíba region of Brazil, 2004-2005.

Results

In the period studied, 63,766 live births (range, 92-20,122) were included. According to data obtained from the DATASUS site, 2,227 children under one year of age were hospitalized for pneumonia (range, 0-573). When hospitalization rates per 1,000 live births were estimated, the mean number of hospitalizations was 35.2/1,000 live births, with a standard deviation of 26.3 (range, 0.0-132.7).

In the spatial analysis, the Moran's global coefficient was 0.37 (p = 0.02), demonstrating a spatial autocorrelation for the hospitalizations for pneumonia in infants under one year of age.

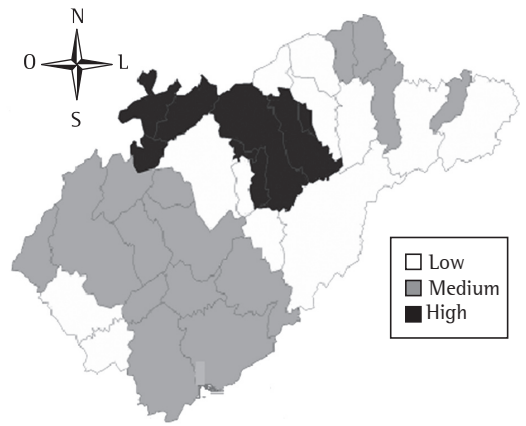

Figure 3 - Distribution of the cities in the Vale do Paraíba region of Brazil, according to their priority for intervention, based on the number of hospitalizations for pneumonia in infants under one year of age.

Figure 2 shows the distribution of hospitalization rates per 1,000 live births, in tertiles. The number of hospitalizations for pneumonia was ≤ 20.6 cases/1,000 live births in the low category, 20.6-40.1 cases/1,000 live births in the medium category and 40.1-137.2 cases/1,000 live births in the high category.

Figure 3 shows the cities using the box map. Eight cities presenting high rates can be identified, as can their neighboring cities, which also presented high rates. Those are cities which need an approach in order to identify the reasons for those high values and to identify in which cities intervention is feasible. When analyzed using Moran's local coefficient, some cites presented no statistical significance, and others, with low rates, presented low values independently of their neighboring cities.

Discussion

This was the first study using georeferencing techniques to analyze hospitalizations for pneumonia in infants under one year of age in the state of São Paulo, Brazil. The importance of studying the distribution of hospitalizations for pneumonia lies in the fact that this disease is traditionally related to infant mortality[9] and that it is subject to social and environmental factors, as well as to the structure of the public health care system, especially the primary care system.

Using the same methodological approach (the spatial point analysis technique), the authors of the study conducted in Goiânia were able to identify areas of greater risk of pneumonia associated with low family income.[14] In that study, pneumonia was confirmed by a pediatrician and X-rays were routinely obtained. Children were hospitalized if warranted based on the severity of the case.[14]

In the present study, we identified clusters of cities within the Vale do Paraíba region in which hospitalization rates were greater than 40 cases/1,000 live births: one consisting of 10 cities and located in the central and northeast region; and two additional clusters, one located in the extreme north and one located in the extremely south. It is of note that these cities are located in two distinct areas. Some of these cities are in the mountainous area, in the Serra

da Mantiqueira and Serra do Mar, and others are along the Presidente Dutra Highway. These cities seem to be associated with two cities with better hospital treatment and to which patients for hospitalization would be referred.

We highlight that, in the health subregion of the mountainous area, there are two circuits of cities for which a deeper, aggregated analysis must be carried out, beyond the administrative borders of the cities, given the proven spatial dependence of the events. The first circuit comprises the cities of Santo Antonio do Pinhal, São Bento do Sapucaí and Campos do Jordão, the last being the center of pediatric hospitalization in this subregion. Among the cities with hospitalization rates that were considered medium (20.6-40.1 cases/1,000 live births), São José dos Campos is the largest city in the region. Probably because it is the largest city in the Vale do Paraíba region, some residents of neighboring cities give addresses in São José dos Campos in order to use its health care facilities, thereby inflating the number of SUS patients attributed to the city.

The diagram devised by Moran identified eight cities in quadrant 1 (cities with high hospitalization rates surrounded by others with high rates). Therefore, it was possible to identify a microregion where an intervention should take place in order to identify possible risk factors and, consequently, decrease these rates. This possible intervention meets the State Plan/Health Pact, with the aid of the RHDs and the College for Regional Management.[15]

One possible limitation of our study is that the diagnoses of pneumonia were not confirmed by X-ray, as was done in the study carried out in Goiânia.[14] However, SUS-sponsored hospitalizations are authorized *a posteriori* by auditors who verify the coherence of the clinical history and the diagnosis, also using, to that end, evidential examinations. This might have reduced the number of diagnostic errors related to hospitalizations for acute respiratory disease. It is also of note that hospitalizations covered by private health insurance plans or by other funding sources were not included. In addition, we excluded pneumonia patients who were treated as outpatients.

Our study shows that, despite being within the same health region, the subregions are distinctly characterized as high-risk areas for pneumonia-related hospitalization in the first year of life. This spatial conformation can have environmental determinants (such as the climate), social determinants (related to economics and education) or even determinants related to the public health care system (coverage, the primary care model and access to procedures of medium complexity, including appointments with specialists and access to hospitals).

We identified spatial clusters with high rates of hospitalization for pneumonia in infants under one year of age, as well as characterizing specific circuits influenced by the neighboring component. These clusters must be evaluated in more details, in an integrated approach to the different levels of health care, aiming at a better understanding of the flow of patients within the system.

Spatial analysis can provide technical information for the discussion of regional strategies of intervention in the management of the health care departments in the cities evaluated in the present study.

References

1. Mulholland K. Magnitude of the problem of childhood pneumonia. Lancet. 1999;354(9178):590-2.
2. Departamento de Informática do SUS - DATASUS [homepage on the Internet]. Brasília: Ministério da Saúde. [cited 2008 Jan 07]. Morbidade Hospitalar do SUS - por local de residência - Brasil. Available from: http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sih/cnv/mruf.def
3. Departamento de Informática do SUS - DATASUS [homepage on the Internet]. Brasília: Ministério da Saúde. [cited 2008 Jan 07]. Internações Hospitalares do SUS - por local de internação - Brasil. Available from: http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sih/cnv/rxuf.def
4. Departamento de Informática do SUS - DATASUS [homepage on the Internet]. Brasília: Ministério da Saúde. [cited 2008 Jan 07]. Óbitos infantis – Brasil. Available from: http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sim/cnv/infuf.def
5. Victora CG, Kirkwood BR, Ashworth A, Black RE, Rogers S, Sazawal S, et al. Potential interventions for the prevention of childhood pneumonia in developing countries: improving nutrition. Am J Clin Nutr. 1999;70(3):309-20.
6. César JA, Victora CG, Barros FC, Santos IS, Flores JA. Impact of breast feeding on admission for pneumonia during postneonatal period in Brazil: nested case-control study. BMJ. 1999;318(7194):1316-20.
7. Nascimento-Carvalho CM, Rocha H, Benguigui Y. Effects of socioeconomic status on presentation with acute lower respiratory tract disease in children in Salvador, Northeast Brazil. Pediatr Pulmonol. 2002;33(4):244-8.
8. Nascimento LF, Marcitelli R, Agostinho FS, Gimenes CS. Hierarchical approach to determining risk

factors for pneumonia in children. J Bras Pneumol. 2004;30(5):445-51.
9. Nascimento LF, Pereira LA, Braga AL, Módolo MC, Carvalho JA Jr. Effects of air pollution on children's health in a city in Southeastern Brazil [Article in Portuguese]. Rev Saude Publica. 2006;40(1):77-82.
10. Nuckols JR, Ward MH, Jarup L. Using geographic information systems for exposure assessment in environmental epidemiology studies. Environ Health Perspect. 2004;112(9):1007-15.
11. Santos SM, Barcellos C, Carvalho MS, Flôres R. Spatial clusters detection of violent deaths in Porto Alegre, Rio Grande do Sul, Brazil, 1996 [Article in Portuguese]. Cad Saude Publica. 2001;17(5):1141-51.
12. Shimakura SE, Carvalho MS, Aerts DR, Flores R. Spatial risk distribution: modeling infant mortality in Porto Alegre, Rio Grande do Sul State, Brazil [Article in Portuguese]. Cad Saude Publica. 2001;17(5):1251-61.
13. Nascimento LF, Batista GT, Dias NW, Catelani CS, Becker D, Rodrigues L. Spatial analysis of neonatal mortality in Paraíba Valley, Southeastern Brazil, 1999 to 2001 [Article in Portuguese]. Rev Saude Publica. 2007;41(1):94-100.
14. Andrade AL, Silva SA, Martelli CM, Oliveira RM, Morais Neto OL, Siqueira Júnior JB, et al. Population-based surveillance of pediatric pneumonia: use of spatial analysis in an urban area of Central Brazil. Cad Saude Publica. 2004;20(2):411-21.
15. Secretaria da Saúde [homepage on the Internet]. São Paulo: Secretaria de Estado da Saúde do Estado de São Paulo. [cited 2008 Feb 11]. Plano Estadual/Pacto pela Saúde (PLANO PACTO). Available from: http://sistema.saude.sp.gov.br/plano_pacto/

About the authors

Adriana de Oliveira Mukai
Assistant Professor. Department of Internal Medicine of the University of Taubaté, Taubaté, Brazil.

Kátia de Souza Costa Alves
Pediatrician. University Hospital of Taubaté, Taubaté, Brazil.

Luiz Fernando Costa Nascimento
Assistant Professor. Department of Internal Medicine of the University of Taubaté, Taubaté, Brazil.