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Spatial distribution of number of Neonatal Intensive Care Units beds in Brazil and its association with child mortality rate

Distribuição espacial de leitos de Unidades de Terapia Intensiva Neonatal no Brasil e sua associação com a taxa de mortalidade infantil

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ABSTRACT
This study aimed at analyzing the spatial distribution of beds in the Neonatal Intensive Care Units (NICU) and correlating it with Live Birth Rate and Child Mortality Rate (CMR) in the Brazilian states. This is an ecological study involving the 27 Brazilian states, with data obtained from health information systems and analyzed using SPSS 20.0 and GeoDa 1.12. There was heterogeneity in the spatial distribution of CMR and NICU, with a higher concentration of NICU beds not belonging to the Unified Health System (SUS) in the Southeast Region and SUS beds in the Northeast Region. CMR showed a negative spatial correlation with the number of beds (Moran's I = - 0.323) in the states of Amazonas and Pará. An inverse relationship between the number of NICUs available and the mortality rate was observed only in two states, which reinforces the importance of further investigating other causes for infant mortality in other states in future studies.

Keywords: Spatial analysis. Child mortality. Neonatal Intensive Care Units.

RESUMO
Esta pesquisa teve o objetivo de analisar a distribuição espacial de leitos de Unidades de Terapia Intensiva Neonatal (UTIN) e correlacioná-la com a taxa de nascidos vivos e a Taxa de Mortalidade Infantil (TMI) das unidades federativas brasileiras. Trata-se de um estudo ecológico, envolvendo as 27 unidades federativas, com dados obtidos de sistemas de informação em saúde e analisados por meio do SPSS 20.0 e GeoDa 1.12. Observou-se heterogeneidade na distribuição espacial da TMI e UTIN, com uma concentração maior de leitos de UTIN não ligados ao Sistema Único de Saúde (SUS) na Região Sudeste e leitos SUS na Região Nordeste. A TMI apresentou correlação espacial negativa com o número de leitos (Moran's I = - 0,323) nos estados de Amazonas e Pará. Concluiu-se que a relação inversa entre número de UTIN disponíveis e taxa de mortalidade limitou-se a dois estados, o que reforça a importância de mais estudos que possam investigar outras causalidades para a mortalidade infantil nas outras unidades federativas.

Palavras-chave: Análise espacial. Mortalidade infantil. Unidades de Terapia Intensiva Neonatal.

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INTRODUCTION

According to the Ministry of Health (Ministério da Saúde - MS), Child Mortality Rate (CMR) refers to the number of deaths of children under one year of age per thousand live births in a given geographical area [1]. This indicator predicts the risk of a live-born child dying before completing the first year of life and is an important indicator of the health status of a population[2]. Although there has been a decrease in CMR in the past two decades, the rate of neonatal death in Brazil is still high compared to that in developed countries [11,12]. Given these disparities, it is important to determine the factors associated with the risk of child death in each state, to implement effective preventive actions [11,12].

Factors associated with the risk of child death most widely discussed in the literature include, among others, the number of hospital beds [3]. However, the Brazilian reality is characterized by a universal health system that is still under implementation[4], with inadequate hospital beds [5], unequal distribution[6], restricted access and differentiation of services [7], ranging from highly equipped units to others without a minimum structure required [8].

According to the Brazilian Society of Pediatrics (Sociedade Brasileira de Pediatria - SBP), the low number of beds directly influences the quality of care, as it hampers early diagnosis and consequently delays the onset of treatment, leading to an increase in CMR [9]. This situation contributes negatively to the fourth Millennium Development Goal (MDG) of the United Nations Children's Fund (Unicef), which advocates reducing childhood mortality[10].

Given the impact of health care on child mortality rate, the present study aims at analyzing the spatial distribution of beds in the Neonatal Intensive Care Units (NICU) in Brazil and correlating it with live birth rate and child mortality by state.

METHODS

This is an ecological study conducted in 2019 involving multiple groups, with secondary data obtained from the National Register of Health Establishments (Cadastro Nacional de Estabelecimentos de Saúde - CNES). Twenty-seven Brazilian states were analyzed, and secondary data available in health information systems were used.

The study variables included the number of NICU beds available in 2016 in the 27 Brazilian states according to CNES, which is the database used for operationalizing the Health Information Systems [12]. Data on the number of beds existing in the SUS and the non-SUS system were extracted by state, and the total number of beds available for that year was calculated from the sum of the beds (SUS + non-SUS). It is worth mentioning that this definition corresponds to the nomenclature suggested by CNES and considers the services available to the public and private systems.

Standardized CMR was also investigated in the present study. Data of the number of child deaths obtained from the Mortality Information System (SIM), and the number of live births, obtained from the Live Birth Information System (Sistema de Informações sobre Nascidos Vivos - Sinasc) was used for calculating the standardized CMT for 2016. Standardized CMT by each state was calculated by the ratio: number of child deaths/number of live births * 1000, and the result was expressed per thousand inhabitants [13].

Descriptive analysis was performed with SPSS 20.0 *software*, and spatial analysis with GeoDa 1.12 *software* (Spatial Analysis Laboratory, University of Illinois, Urbana Champaign, United States). The spatial dependence of the variables was analyzed by the Moran Index (Moran's I), which estimates the spatial autocorrelation and varies from -1 to +1, indicating the direction of the correlation and the magnitude of the correlation from zero to 1 and constructing MoranMaps to determine the presence of *clusters*.

Maps were created with the mortality variables and independent variables distributed in quartiles,

and *clusters* analyzed and distributed according to the standard deviation. The population of each state was obtained from the 2010 Census information on the website of the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística - IBGE).

Bivariate Moran's I LISA (Local Indicators of Spatial Association) analysis was performed to determine the spatial correlation between the child mortality rate and independent variables. Thematic maps were constructed for each association pair, thus determining the pattern of spatial dependence (*clusters*) and the statistical significance ($p < 0.05$).

RESULTS

Data of the five regions of Brazil (North, Northeast, Midwest, Southeast, and South), comprising 26 states and the Federal District, were collected. A total of 2,857,800 live births and 36,350 cases of death up to one year of age, 4,801 SUS, and 4,158 non-SUS NICU beds were recorded in Brazil in 2016.

The descriptive analysis of CMR in Brazil and its states (Table 1) showed that the highest death rate was in the North Region, with an average of 15.64 deaths per 1,000 live births. The South Region had the lowest rate of infant deaths, which was 27.6% lower than the national average.

Table 1. Descriptive analysis of the child mortality rate in Brazil and its states

Geographical area	Average death rate	Median death area	25th percentile	75th percentile	Minimum death rate	Maximum death rate
Brazil	13.55	13.42	12.08	15.25	8.75	18.46
North	**15.64**	15.67	14.28	17.13	12.48	18.46
Northeast	14.32	14.31	12.81	15.36	12.64	16.24
Midwest	12.52	12.97	12.26	13.22	10.31	13.82
Southeast	11.97	11.59	11.39	12.17	11.09	13.64
South	9.81	10.18	9.46	10.34	8.75	10.51

Note: CMR expressed per thousand inhabitants.
Source: Prepared by the author, 2020.

The North, Northeast, and South regions have a higher number of beds offered by SUS; in the Southeast Region, a higher number of beds is offered by the non-SUS services - which also have a higher distribution of beds per thousand live births (Table 2).

Table 2. Neonatal ICU beds (SUS, non-SUS, and total) and their distribution per thousand live births

Region/State	Neonatal ICU beds			Distribution
	SUS	Non-SUS	Total	Total
North	**313**	**280**	**593**	**1.93**
Acre	15	5	20	1.27
Amazonas	64	71	135	1.76
Roraima	8	4	12	1.05
Rondônia	26	29	55	2.07
Pará	153	150	303	2.20
Amapá	9	11	20	1.29
Tocantins	38	10	48	2.01
Northeast	**1,064**	**490**	**1,554**	**1.95**
Maranhão	132	48	180	1.63
Piauí	37	24	61	1.30
Ceará	221	48	269	2.13
Rio Grande do Norte	75	49	124	2.73
Paraíba	58	31	89	1.59
Pernambuco	124	119	243	1.86
Alagoas	90	73	163	3.38
Sergipe	109	12	121	3.76
Bahia	218	86	304	1.52
Midwest	**322**	**415**	**737**	**3.14**
Mato Grosso	93	117	210	3.92
Goiás	105	148	253	2.65
Mato Grosso do Sul	44	50	94	2.22
Federal District	80	100	180	4.15
Southeast	**2,209**	**2,530**	**4,739**	**4.20**
Minas Gerais	574	310	884	3.49
São Paulo	1129	1119	2248	3.74
Espírito Santo	128	153	281	5.26
Rio de Janeiro	378	948	1326	6.05
South	**893**	**443**	**1,336**	**3.41**
Paraná	396	170	566	3.65
Santa Catarina	151	80	231	2.42
Rio Grande do Sul	346	193	539	3.81
BRAZIL	4801	4158	8959	3.13

Note: Distribution: Total NICU beds/1,000 live births.
Source: Prepared by the author, 2020.

The spatial distribution of the number of NICU beds followed a geographic pattern, with a higher number of beds in the Southeast Region (Figure 1A) - associated with greater availability of non-SUS beds (Figure 1C), while the Northeast Region had a higher number of SUS beds (Figure 1B).

Spatial dependence analysis showed that states with significant clusters having a high concentration of the total number of beds (Figure 1D) were Rio de Janeiro, São Paulo, and Minas Gerais (Moran's I = 0.353, $p \leq 0.05$). They also had significant high-high clusters for the total number of non-SUS beds (Figure 1F) (Moran's I = 0.354, $p \leq 0.05$). São Paulo, Rio de Janeiro, and Paraná had significant high-high clusters for the total number of SUS beds (Figure 1E) (Moran's I = 0.271, $p \leq 0.05$).

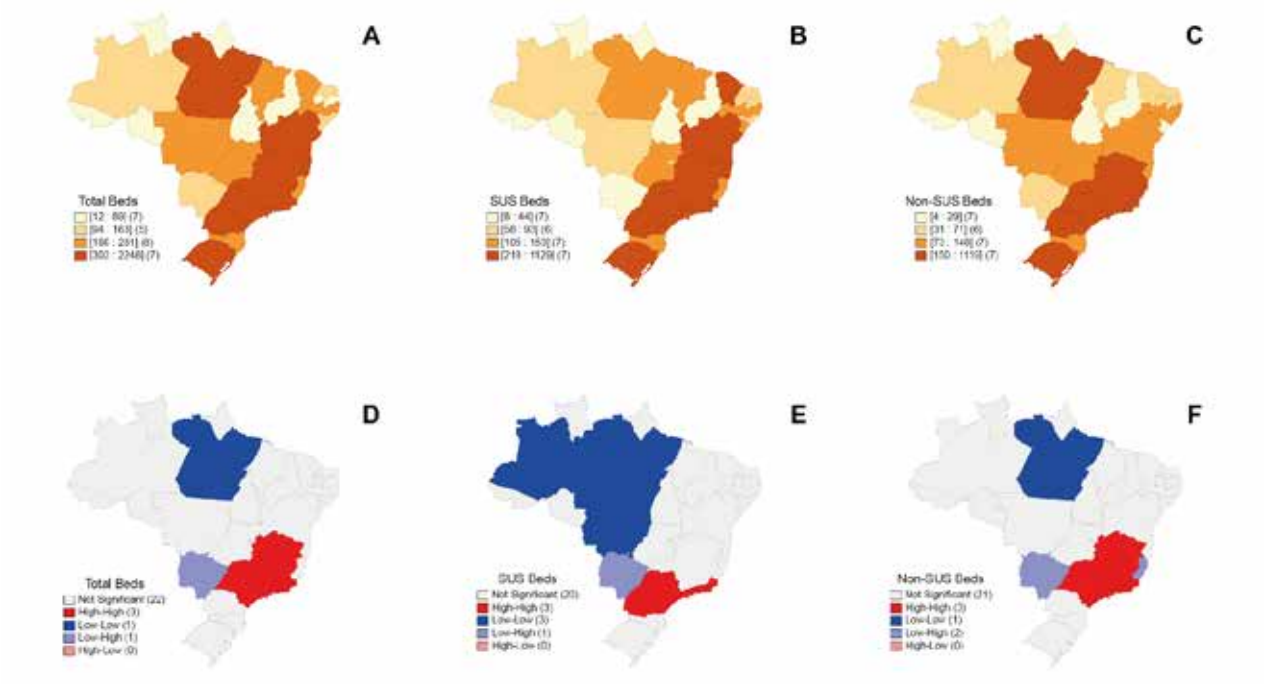

Figure 1. Spatial distribution of the total number of beds (1A), SUS beds (1B) and non-SUS beds (1C) with the respective Moran Map autocorrelation maps and their statistical significance for the total number of beds (1D), SUS beds (1E), and non-SUS beds (1F).
Source: Prepared by the author, 2020.

Spatial bivariate analysis showed a negative spatial correlation between CMR and the total number of beds (SUS + non-SUS) (Moran's I = -0.323), the number of SUS bed (Moran's I = -0.335), and the number of non-SUS beds (Moran's I = - 0.288). Significant *clusters* with a low number of NICU beds and high mortality were observed in Amazonas and Pará for all associated pairs. Santa Catarina was the only state with the number of beds below the recommended number and the lowest child mortality rate (Figure 2A, 2B, and 2C).

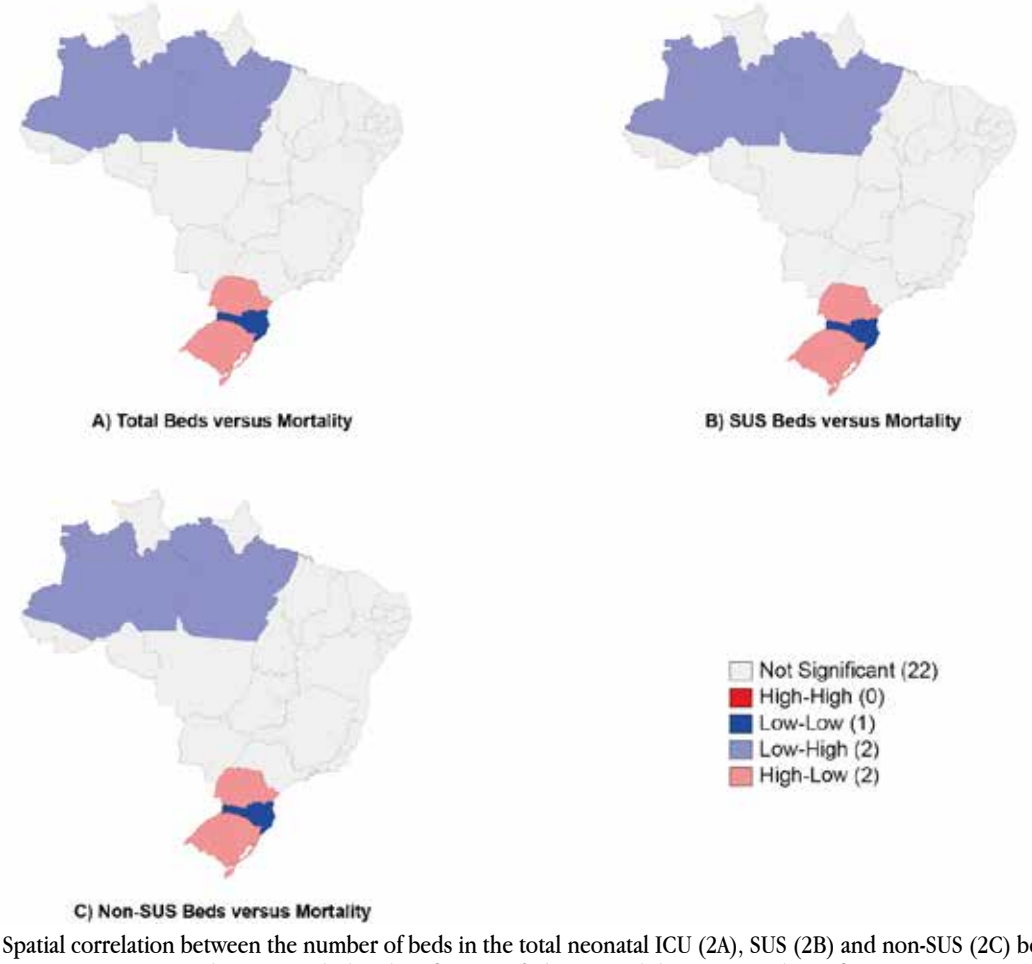

Figure 2. Spatial correlation between the number of beds in the total neonatal ICU (2A), SUS (2B) and non-SUS (2C) beds and child mortality rate, with the identification of *clusters* and their statistical significance.

Source: Prepared by the author, 2020.

DISCUSSION

Heterogeneity was observed in the spatial distribution of NICU beds in Brazil, which correlated with CMR by state, in the spatial distribution of CMR and NICU. Although a higher CMR was observed in the North Region, it was not correlated with the number of beds. Although the Southeast Region had the largest number of beds, a spatial correlation between a high number of beds and low infant mortality was observed in the South - more specifically in the states of Paraná, and Rio Grande do Sul. Ordinance No. 930 of the Ministry of Health recommends that two NICU beds be available for every thousand live births [13]. The Scientific Department of Neonatology of the Brazilian Society of Pediatrics (SBP) follows a proportion of four beds for every thousand live births, distributed regionally and in a hierarchical system of perinatal care[14].

The data shows that the Midwest, Southeast, and South regions have the number of beds in accordance with the recommendation of the Ministry of Health and have the lowest child mortality rates. Although Southeast is the only region with beds per the SBP recommendations; however, if the number of beds provided by SUS is considered, the index is below the two established parameters, which causes a conflict. This is because the number of beds only when non-SUS beds is considered violates what is proposed by the Unified Health System, which says health as a right for all and a duty of the State [15].

The difficulty in accessing maternal and child health services is considered one of the causes of the

uneven distribution of neonatal mortality in Brazil [18.19]. This study showed an association between low availability of NICU beds and high CMR, corroborating the results by Oliveira et al. [18]. The authors indicate socioeconomic difficulties, which lead to worse health indicators compared to other Brazilian regions, as one of the possible causes of high CMR [20].

A World Bank study showed that Brazil had the highest proportion of social inequality in child mortality among the nine developing countries analyzed. This results from social inequalities and limited access to health[15]. Multiple factors that affect neonatal mortality - social, economic, and related to basic health care and highly complex maternal and child care should be considered to reduce these rates[15].

In contrast, Rio Grande do Sul and Paraná have a high number of beds and low mortality, corroborating the results of Frank et al. [22] and Rocha et al. [23], which attribute these findings to good effectiveness of neonatal care and the indirect role of maternal and child care.

In addition to better service, networking is an important factor in understanding the mortality rates. It should be noted that the Rede Mãe Paranaense program was implemented in Paraná in 2011 e 2012 for maternal and child care through specialized monitoring, from the early identification of pregnant women at risk until the child reached 12 months of age [23]. Following the implementation of this initiative, maternal and child mortality indicators decreased due to the training of health professionals in maternal and child care [23.24].

An interesting finding of this study was the significant relationship between the low number of beds and low CMR in only one state in the Southern Region, Santa Catarina. This result suggests that the CMR is multifactorial [27]. Sousa et al. [28] suggested that it has an inverse relationship with socioeconomic indices; thus, the higher the CMR, the lower the socioeconomic level in the region.

This finding in Santa Catarina might be associated with the healthcare actions undertaken. According to data from the State Department of Health, the state now has 16 Action Plans of the Rede Cegonha approved by the Ministry of Health within the scope of the Unified Health System 2011. It was the first Health Care System with full state coverage and the first Cegonha Network with state coverage in Brazil, with annual investment in funding resources that exceed the national average[25.29].

Although evidence shows that the perinatal health results are due to obstetric and neonatal efficacy [30-32], economic and social development seems to contribute to this indicator[12.16.28.33]. Lisa, Flore, and Sandrine[33] reported that factors related to per capita income and basic sanitation contributed to reducing CMR in 100 developing countries. Garcia and Santana[34] further state that poor maternal education is associated with higher CMR.

The findings of the present study suggest that the socioeconomic inequality in Brazil seems to also influence the distribution of the number of beds and CMR, with a concentration of deaths in low-income social groups. However, only the number of beds was assessed using the CNES platform, and only data from 2010 were compiled. This can lead to a discontinuity of the base [40] data and consequently limit the interpretation of the results. However, it is noteworthy that the authors considered data from the date closest to the year of documentation of child mortality rates.

Moreover, despite using ecological correlations, this study will certainly guide public policies and can be used as a criterion for a more equitable distribution of public resources, prioritizing regions with worse health indicators.

CONCLUSION

The spatial distribution of child mortality rate and the number of neonatal beds in Brazilian regions and states was heterogeneous.

Spatial analysis showed an inverse relationship between the number of available neonatal beds

and the mortality rate in only two Brazilian states. This finding reinforces the importance of further investigating other causes of child mortality in other states in future studies.

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