Spatial distribution of traumatic brain injury cases seen at the trauma units of reference in Salvador, Bahia, Brazil

Distribución espacial de los casos de traumatismos craneoencefálicos atendidos en unidades de referencia en Salvador, Bahía, Brasil

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ABSTRACT An exploratory study was performed with patients who suffered traumatic brain injuries (TBI) in the period from July 31, 2007 to August 1, 2008. The spatial distribution of the TBI cases seen at the trauma unit of reference in the Metropolitan Region of Salvador, Bahia, Brazil was analyzed. Both the residential addresses and places of occurrence were geocoded by means of GPS receiver devices. The spatial aggregation of cases was evaluated using the nearest neighbor hierarchical clustering technique in the CrimeStat® 3.2 program. TBI cases were not randomly distributed; rather, they formed clusters in relation to both place of residence and place of occurrence of the trauma. Many of the clusters were identified in areas far removed from the locations of emergency services as well as from the locations where multi-professional rehabilitation is offered. Thus, the spatial distribution of the health services, in relation to the places of occurrence of TBI, reveals inequalities.

KEY WORDS Georeferencing; Craniocerebral Traumas; Spatial Distributions; Health Services Accessibility; Brazil.

RESUMEN Se realizó un estudio exploratorio con pacientes que sufrieron traumatismos cráneoencefálicos (TCE) entre el 31 de julio del 2007 y el 1 de agosto del 2008. Se analizó la distribución espacial de los casos atendidos en la unidad de referencia para traumatismos de la Región Metropolitana de Salvador, Bahía, Brasil. Los domicilios residenciales y los lugares de ocurrencia de los TCE fueron geocodificados por medio del dispositivo receptor Global Positioning System (GPS) y se realizó la agregación espacial de los casos por medio de la técnica de conglomerados jerárquicos de vecinos más próximos utilizando el aplicativo CrimeStat® 3.2. Los casos de TCE no se distribuyeron de forma aleatoria sino formando conglomerados, tanto en relación con los domicilios de residencia como con el lugar de ocurrencia. Muchos de los conglomerados se identificaron en áreas distantes de los lugares de atención a la urgencia y de los lugares en que se ofrece rehabilitación multiprofesional, por lo que la distribución espacial de los servicios de salud, en relación con los lugares de ocurrencia de los TCE, revela inequidades.

PALABRAS CLAVES Georreferencia; Traumatismos Craneoencefálicos; Distribución Espacial; Accesibilidad a los Servicios de Salud; Brasil

INTRODUCTION

Despite the numerous advances that have made in the prevention and treatment of injuries caused by accidents and violence, these avoidable causes of morbidity and mortality continue to jeopardize millions of lives (1-4). Since the 1980s, external causes of death have become one of the leading causes of death or disability in young adults in Brazil (5-12). These types of potentially serious injuries, when not leading to death, are likely to change permanently the abilities and prospects of patients and their families (13-15).

Taking into account the devastating effects these injuries can cause in the lives of the survivors and their families in terms of temporary or permanent physical, cognitive, or emotional damage, it is necessary to bring together a wide range of interventions, from preventive primary care to emergency care and rehabilitation (13,14,16,17). Public health institutions around the world, such as the Centers for Disease Control and Prevention (CDC) in the United States, have especially called attention to the need for systematic and continuous surveillance of the problem in order to reduce its incidence (1,2,4).

The surveillance of traumatic brain injuries (TBI) can help identify risk factors susceptible to intervention and can represent a significant step in addressing such factors. Particularly, Geographic Information Systems (GIS) are useful tools for the understanding of the epidemiological profile of these events in the health of individuals, by exploring their relation to the spatial distribution of health centers where urgent care is provided, as well as health centers providing clinical and physiotherapeutic care of sequelae (1,2,4,18). Thus, this study seeks to describe the spatial distribution of the TBI cases treated in the hospital of the Metropolitan Region of Salvador, Bahia, Brazil between July 31, 2007 and August 1, 2008.

METHODS

An exploratory study was conducted in patients suffering from TBI and admitted into the emergency services of a public hospital – the facility of reference for the care and treatment of injuries in the Metropolitan Region of Salvador, Bahia, Brazil – between July 31, 2007 and August 1, 2008. The region, also known as Greater Salvador, had at the time of the study a population of 3,866,004 inhabitants (19).

The study included patients with a suspected diagnosis of TBI suffering specific neurological symptoms such as loss of consciousness, disorientation, mental confusion, behavioral disorders, somnolence, dizziness, convulsions, nausea, vomiting and post-traumatic amnesia.

For the initial data collection, the patient care forms filed at the Department of Medical Records and Statistics (SAME) [*Serviço de Arquivo Médico e Estatística*] were consulted and the residential addresses of the patients were recorded. For the cases that were included in a cohort that was followed over the course of a year, data on place of TBI occurrence were gathered from relatives and friends and the spatial location was obtained through different information exchange agreements with the Mobile Emergency Care Service (SAMU) [*Serviço de Atendimento Móvel de Urgência*], the Care and Transportation of Victims of Accidents and Rescue Service (SALVAR) [*Serviço de Atendimento e Locomoção de Vítimas de Acidentes e Resgate*], and the Civil Police of Bahia.

The altitude and coordinates of the locations where events took place and the residential addresses of those patients living in the Metropolitan Region of Salvador were obtained through a highly sensitive device that operates with the Global Positioning System (GPS), the ETrex Legend HCx Garmin®. The coordinates collected during fieldwork were transcribed onto an Excel worksheet and later converted into .dbf (dBase) files to be used directly with the CrimeStat® 3.2 software (20). In order to evaluate the spatial aggregation of the events, the Nearest Neighbor Hierarchical Clustering (NNHC) technique – which involves clustering points or cases according to their spatial proximity – was used. Therefore, the parameters utilized consisted of a standard deviational ellipse with a minimum of 10 points for each cluster and Euclidian distance. These procedures allowed first-level neighbor clusters (local clusters) and second-level neighbor clusters (large-scale clusters) to be identified. The ArcView® 3.2 software was used to make the thematic maps. The research
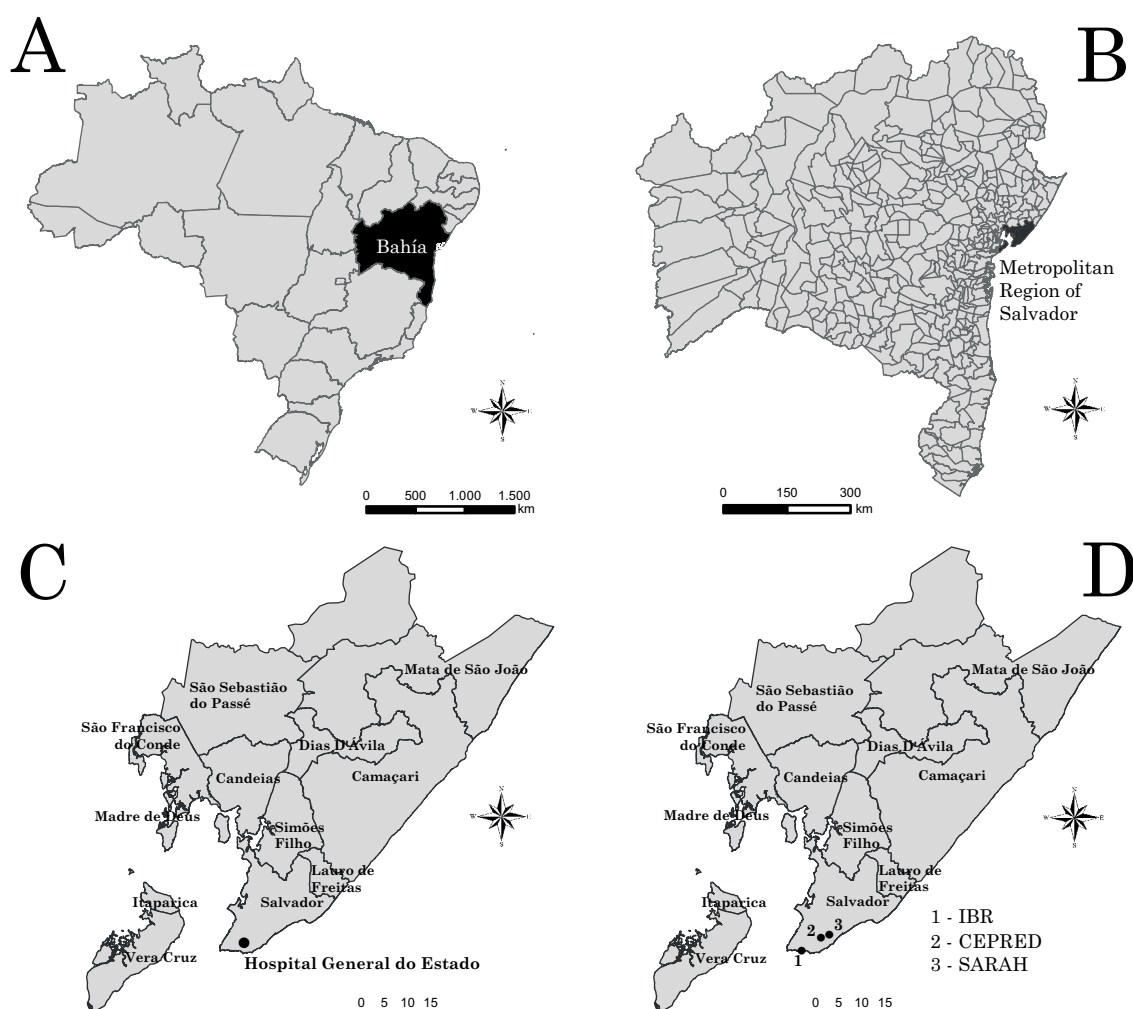
Figure 1. Spatial distribution of health services of reference for the care and treatment of traumatic brain injuries in the Metropolitan Region of Salvador, Bahia, Brazil, 2007-2008.

Source: Own elaboration.

Note: A) State of Bahia, Brazil. B) Metropolitan Region of Salvador. C) Hospital General do Estado, facility of reference for trauma care and treatment in the Metropolitan Region of Salvador. D) Health centers that offer multidisciplinary rehabilitation within the Unified Health System (SUS) [*Sistema Único de Saúde*].
IBR = Institute of Rehabilitation of Bahia [I*nstituto Bahiano de Reabilitação*]. CEPRED = State Center for the Prevention and Rehabilitation of Deficiencies [*Centro de Prevenção e Reabilitação da Pessoa com Deficiência*]. SARAH = Sarah Rehabilitation Hospital.

project was approved by the Ethics Committee of the Instituto de Saúde Coletiva of the Universidade Federal da Bahia (No. 054-06/06).

RESULTS

Figure 1 shows, in addition to the geographic position of the Metropolitan Region of Salvador within the state of Bahia, the locations of the health centers of reference for the care and treatment of traumatic injuries in the area. Map C shows the geographical position of the Hospital General do Estado (HGE) of Bahia, facility of reference for the care and treatment of traumatic injuries within the administrative region of Brotas. Map D shows the points related to the facilities of reference for rehabilitation. These are: the Institute of Rehabilitation of Bahia (IBR) [*Instituto Bahiano de Reabilitação*]

Table 1. Characteristics of patients with traumatic brain injury whose addresses were geocoded, according to the cause of the event. Salvador, Bahia, 2007-2008

Characteristics	Traumatic brain injuries				
	Accidents (n= 1,245)		Intentional violence (n= 327)		*p*-value*
	n	%	n	%	
Age (in years)					
0 to 15	404	32.7	18	5.6	
16 to 25	228	18.5	120	37.1	
26 to 35	232	18.8	102	31.6	
36 to 45	154	12.5	51	15.8	
46 to 55	117	9.5	20	6.2	<0.001
56 to 65	55	4.4	11	3.4	
66 to 75	30	2.4	1	0.3	
76 to 85	12	1.0	0	-	
86 +	3	0.2	0	-	
Sex					
Male	875	70.3	276	84.4	<0.001
Female	370	29.7	51	15.6	
Location reported as the site of the event[a]					
Residential address	166	30.5	19	15.3	
Public place	337	61.9	92	74.2	0.005
Work	21	3.9	5	4.0	
Other	20	3.7	8	6.5	

Source: Own elaboration.

**Pearson's chi-square.

[a]Unknown data: 904 cases, 701 in males and 203 in females.

in the administrative region of Barra/Ondina; the Sarah Rehabilitation Hospital (SARAH) in the administrative region of Pituba/Costa Azul, and the State Center for the Prevention and Rehabilitation of Deficiencies (CEPRED) [*Centro de Prevenção e Reabilitação da Pessoa com Deficiência*] in the border area between the administrative region of Brotas and Pituba/Costa Azul.

Table 1 shows general information about TBI cases according to their etiology (accidents or intentional violence). The addresses of 1,572 patients admitted to the trauma unit of reference for the Metropolitan Region of Salvador were obtained. Statistically significant differences could be observed regarding sex, age and place of occurrence with respect to the trauma etiology. Males were generally more affected, and intentional violence most affected the 16-25 year age group. Trauma occurred more frequently in public places.

With the geocoding of the 1,572 residential addresses of patients with TBI living in the Metropolitan Region of Salvador, 41 first-level clusters and 4 second-level clusters (Figure 2) were identified. In the administrative region of Subúrbio Ferroviário, 6 primary clusters were identified and grouped into a secondary cluster.
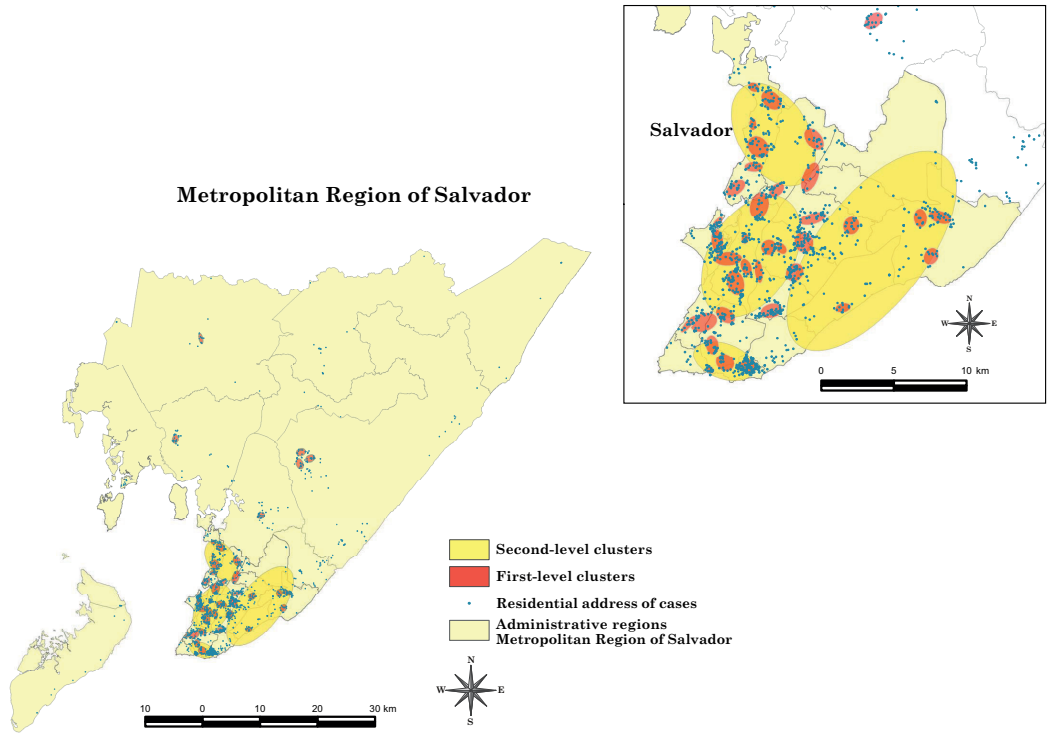
Figure 2. Residential addresses of TBI patients treated at the Emergency Care Department of the Hospital General do Estado between July 31, 2007 and August 1, 2008, and the first- and second-level clusters. Salvador, Bahia, Brazil.
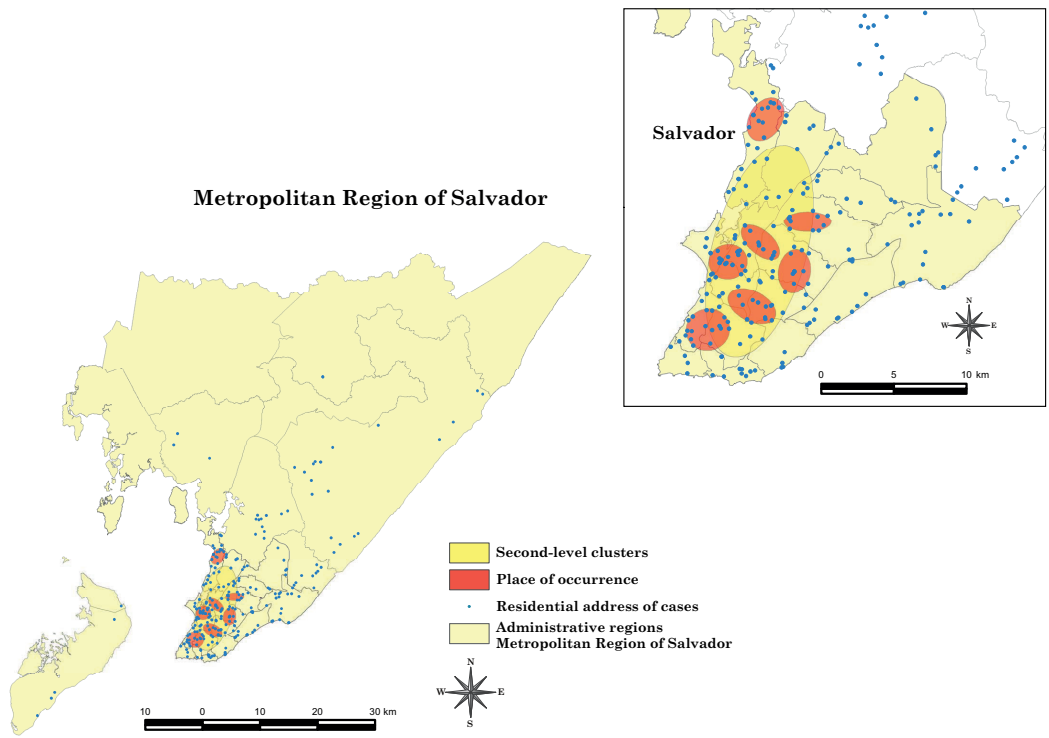
Source: Own elaboration.

Figure 3. Place of occurrence of the cases of traumatic brain injuries treated at the emergency department of the Hospital General do Estado between July 31, 2007 and August 1, 2008, and first- and second-level clusters. Salvador, Bahia, 2007-2008.

Source: Own elaboration.

Table 2. Characteristics of traumatic brain injury cases in which the place of occurrence was geocoded, by cause. Salvador, Bahia, 2007-2008.

Characteristics	Traumatic brain injuries				
	Accidents (n= 164)		Intentional violence (n= 99)		*p*-value*
	n	%	n	%	
Age (in years)					
0 to 15	2	1.2	2	2.0	
16 to 25	38	23.2	47	47.5	
26 to 35	50	30.5	31	31.3	<0.001
36 to 45	36	21.9	11	11.1	
46 to 55	29	17.7	5	5.0	
56 to 65	9	5.5	3	3.0	
Sex					
Male	163	99.4	99	100.0	0.436
Female	1	0.6	0	-	
Location reported as the site of the event[a]					
Residential address	9	21.9	1	6.2	
Public place	27	65.8	12	75.0	0.509
Work	4	9.8	4	12.5	
Other	1	2.4	1	6.2	
First aid/transportation[b]					
SAMU/SALVAR	88	55.7	26	29.5	<0.001
Acquaintances/friends/coworkers	70	44.3	62	53.5	

Source: Own elaboration.

*Pearson's chi-square.

[a]Unknown data: 204 cases, 123 in males and 81 in females.

[b]Unknown data: 17 cases, 6 accidents and 11 due to intentional violence. SAMU = Mobile Emergency Care Service [*Serviço de Atendimento Móvel de Urgência*]. SALVAR = Care and Transportation of Victims of Accidents and Rescue Service [*Serviço de Atendimento e Locomoção de Vítimas de Acidentes e Resgate*].

Within the first-level clusters, the frequency observed fluctuated between 13 and 17 occurrences, adding up to a total of 166 cases. A large second-level cluster was formed encompassing 9 first-level clusters identified in the administrative regions of Liberdade, Tancredo Neves, Cabula and São Caetano. The estimated frequency in this region was 294 cases. In the administrative regions of Brotas, Federação and Rio Vermelho, 3 first-level clusters that formed a second-level cluster were observed and a total of 226 cases of traumatic brain injuries were registered. Lastly, the fourth second-level cluster observed encompassed the regions of Pituba/Costa Azul and Boca do Rio/Patamares. The first-level clusters of this location add up to a total of 219 cases. Also, first-level clusters were observed in the regions of Simões Filho with 21 cases, Candeias with 20, Camaçari

with 45 cases grouped into 3 clusters, Centro and Saúde with 45 and Pernambués with 64 (Figure 2).

Despite the efforts made to collect data from patient's relatives, civil police and professionals of the administrative department of the SAMU and SALVAR mobile pre-hospital care services, it was only possible to gather information about the place of occurrence in 246 of the cases (Table 2) that made up the cohort.

Figure 3 shows 7 first-level clusters related to the place of TBI occurrence in the administrative regions of Centro, Liberdade, Brotas, Cabula, Tancredo Neves, São Caetano and Subúrbio Ferroviário which were regrouped into a second-level cluster. The frequency of cases in each first level cluster varied from 11 to 29.

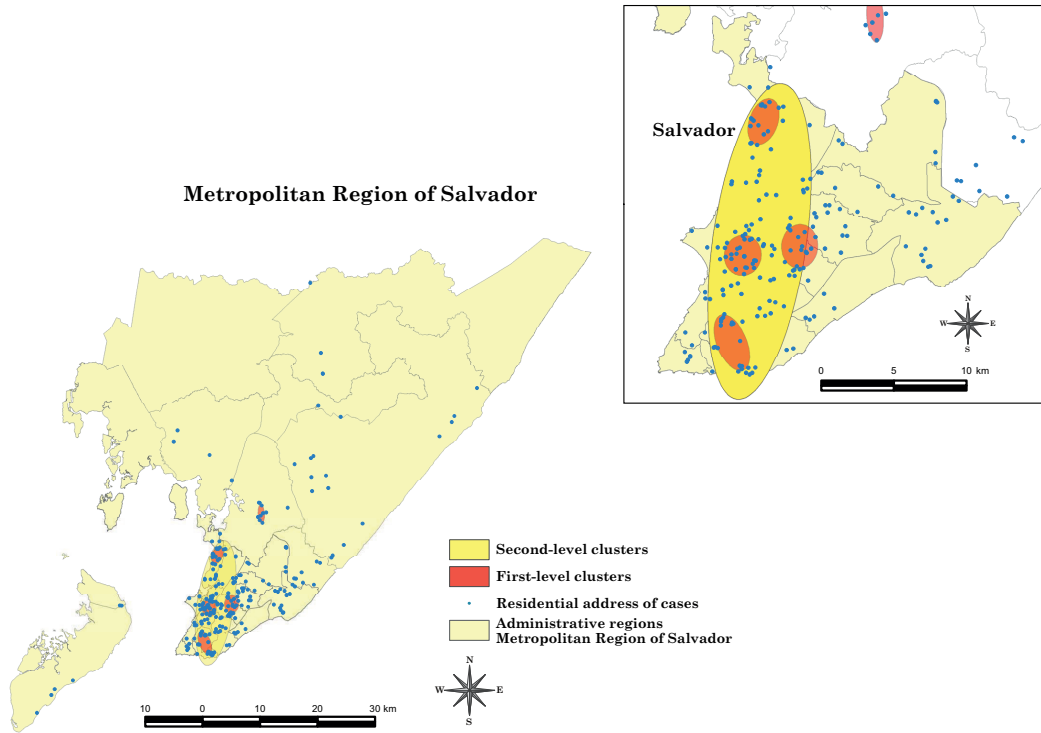Figure 4 shows the points related to the geocoding of the residential addresses of the

Figure 4. Residential addresses of patients with traumatic brain injury treated at the emergency department of the General Hospital do Estado between July 31, 2007 and August 1, 2008, and first- and second-level clusters. Salvador, Bahia, 2007-2008.
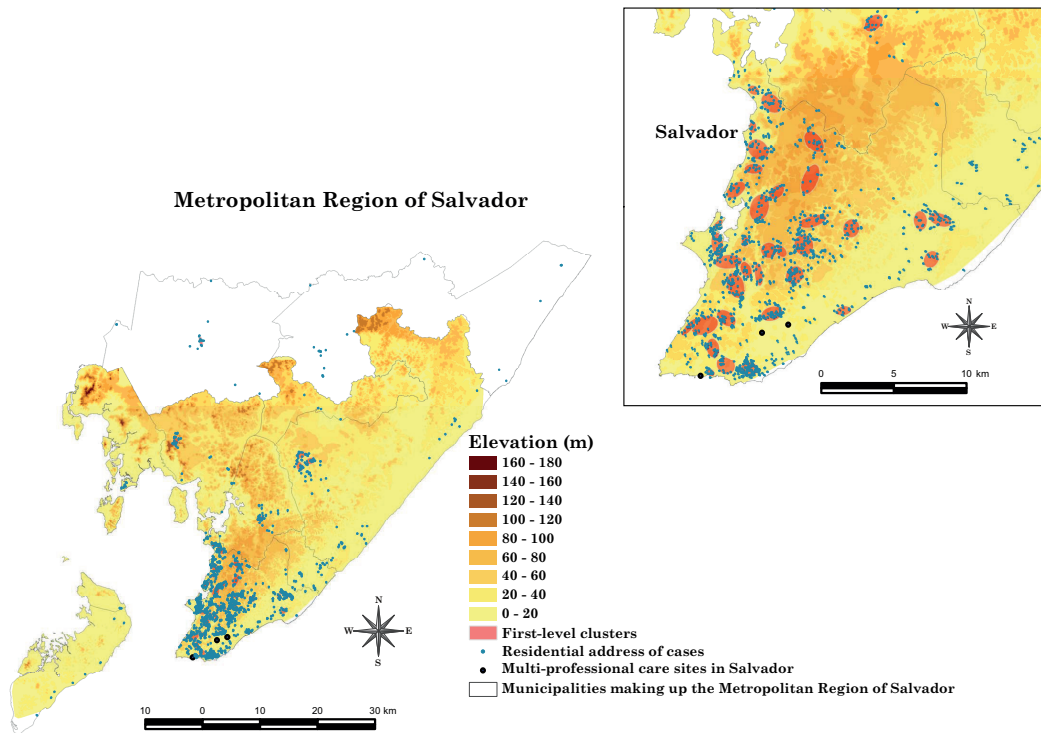
Source: Own elaboration.

Figure 5. Topography of the Metropolitan Region and Salvador (detail) and residential addresses of TBI patients treated at the emergency department of the Hospital General do Estado between July 31, 2007 and August 1, 2008. First-level clusters and rehabilitation centers. Salvador, Bahia.

Source: Own elaboration.

patients for which the place of occurrence was identified. First-level clusters were formed in the administrative regions of Brotas, Cabula, Liberdade and Subúrbio Ferroviário, grouped in a second-level cluster, and another first-level cluster can be observed in the region of Tancredo Neves.

Figure 5 shows the topographic design of the Metropolitan Region of Salvador, the points referring to the residential addresses of the 1,572 studied patients, the first-level clusters and the multi-professional care centers in Salvador. Case clusters are observed in what is referred to as the "center" of Salvador which corresponds to the administrative regions of Centro, Liberdade, São Caetano, Cabula and Tancredo Neves; there, the topography shows elevations from 80 to 140 meters above sea level.

DISCUSSION

The distribution of the TBI cases treated at the facility of reference of the Metropolitan Region of Salvador, Bahia, is quite heterogeneous and forms first-and second-level clusters. The formation of such clusters may suggest a higher population density in these areas, as well as the existence of factors defined as social determinants of these diseases, "the causes of the causes" of damage to health (21). In the Metropolitan Region of Salvador, these "causes of the causes" may be contributing not only to the occurrence of these injuries, but also potentially to the production and social concentration of the physical and cognitive sequelae derived from TBI in the poorest population, as many of the clusters studied are far from the neurological and neurosurgical emergency centers, as well as from the centers offering multidisciplinary rehabilitation care under the Brazilian Unified Health System (SUS) [*Sistema Único de Saúde*].

The TBI cases assessed were clustered according to the patients' residential addresses and the place of occurrence of the event. Specifically, for the points corresponding to residential addresses, first-level clusters were identified in administrative regions far from the emergency services, such as Subúrbio Ferroviário, Candeias, Camaçari, Liberdade, Tancredo Neves, Cabula, São Caetano, Boca do Rio/Patamares and Pernambués. For these

regions, the total rates of unemployment, that is to say, the "situation of involuntary non-employment due to lack of job opportunities, or engagement in irregular jobs with the desire to change" (22), were high for the 2003-2004 period, as were the rates of homicide (16,0%) and functional illiteracy (19,6%) (23).

Although it is not possible to affirm that the TBI cases in our research study occurred in places near the patients' residential addresses, other researchers have noted associations in this regard. In this study, as data was not obtained for the places of occurrence of all the cases in which home addresses were registered, different maps were used to geocode place of occurrence and place of residence. Although it is not possible to affirm a spatial correlation between the place of occurrence and the place of residence – that is, to affirm that the individuals that form the primary clusters in the place of occurrence map are the same individuals that form the clusters observed in the residential map – it is possible to observe in the distribution that the places of residence were in general close to the places of occurrence.

In a study on the spatial distribution of violence-related deaths in Rio Grande do Sul (4), the authors found that the places of occurrence of events were very close to the victims' places of residence, and estimated that in 67.3% of the cases the maximum distance between the place of occurrence of the assault and the victim's place of residence was about 1 kilometer, while in 50.0% of the cases the maximum distance was 310 meters. The authors note the proximity between the places of residence and that of occurrence in cases connected to traffic accidents. Assuming this association is plausible in this study as well, it is possible to reveal another aspect concerning the social inequality in TBI occurrence. It is precisely in the regions where a small population group with higher income is concentrated – a group made up of important employers, leaders of public and private sectors, self-employed professionals or high-level employees – located in the Atlantic border of the city or in the areas that are considered "noble" in Salvador, where the offer of health services, even that of public services, is concentrated.

Also, first-level clusters were formed in locations closer to the Hospital General do Estado.

It was possible to find clusters in the administrative regions of Pituba/Costa Azul, Brotas, Rio Vermelho/Federação and Centro. The second-level clusters encompassed, on one hand, the administrative regions of Pituba/Costa Azul, Boca do Rio/Patamares, Brotas and Federação/Rio Vermelho and, on the other hand, the administrative region of Barra Ondina. Although in these areas higher rates of formal employment, higher education and access to goods and health services were found, a spatial vision of the city of Salvador suggests, in reality, deep structural differences throughout its territory.

Unemployment rates in the diverse municipalities that form the Metropolitan Region are high and have been veiled in many occasions by low-paid unstable jobs, something which can also explain the spatial distribution of wealth and poverty (23). Wealth is visibly concentrated in the neighborhoods and areas of the administrative regions of Barra/Ondina and Pituba/Costa Azul, to which the neighborhoods of Barra, Ondina, Canela, Vitória, Graça, Pituba and Itaigara belong, as well as in the coastal area of Lauro de Freitas. Poverty is more accentuated in São Francisco do Conde, Itaparica, Vera Cruz and Simões Filho, the inner regions of Lauro de Freitas and Camaçari, and in certain localities of Salvador, such as the administrative regions of Itapagipe, Subúrbio Ferroviário, Pau da Lima, Cajazeiras, Itapagipe and Valéria, which include the neighborhoods of Alagados, São João, Periperi, Fazenda Coutos, Águas Claras and Cajazeiras. In the administrative region of Itapuã, Barrio da Paz stands out, as it presents a very different profile from that observed in the littoral regions of the same area. These findings represent well the situation of residential segregation and its effects on unequal access to the job market, as well as to urban goods and services, and to health services.

Considering that the data used to elaborate this study were based on the information collected from an emergency services unit that reflects the hospital demand, the agglomeration of points shown near the hospital region was to be expected, mainly because it is a facility of reference for trauma care and treatment in the Metropolitan Region of Salvador and because, in general, pre-hospital care services take victims to the nearest public hospitals. Similar results were also found by other authors (24) in the city of São Paulo. Nevertheless, agglomerations far from the base hospital were also identified and are likely an indication of the previously mentioned problems regarding the offer of neurological and neurosurgical emergency services in the city. Even though they are based on data from a single hospital, these results may be considered representative of the local situation, as this is the only hospital of reference for neurological and neurosurgical care that forms part of the SUS in the capital city of the state.

To meet the objectives of this study, events were informed using maps of points and not areas. Therefore, it was not the purpose of this study to estimate disease density or areas of risk for accidents or violence, mostly because the events identified in the study do not represent the total number of cases that occurred in the selected period of time. The obtained data represent TBI patients residing in the Metropolitan Region of Salvador who survived the event and were later admitted. It is not intended to make inferences regarding risks. It should be noted that the concentration of TBI cases in the central regions of Salvador may also be the result of a higher population density in the region; that is to say, in the areas that are highly populated there also are more occurrences of accidents and violence.

It is well known that patients who survive traumatic brain injuries may live with cognitive disability or physical dysfunction (13,14,16,17,25). TBIs may also result in emotional and behavioral disturbances. These deficiencies may be temporary or permanent and may cause partial or total disability, in addition to psychosocial maladjustment (15). Moreover, TBIs classified as mild, contusions included, may cause long-term cognitive problems, affect the ability to carry out everyday activities and to resume work-related activities (4,26-33). The time elapsed between the occurrence and the first emergency care received is considered fundamental. For the victims of traumatic injuries, proper care within an hour of the occurrence – the so called "golden hour" – may represent less functional compromise later on. In this study it was possible to identify the pre-hospital care of just 23 individuals, only 16.7% of the total patients whose addresses were geocoded. As for the victims of violence, it was observed that they were more frequently transported

by acquaintances, friends or coworkers instead of the SAMU and SALVAR services of the Fire Department, a form of transport which does not help lessen the impact of distance as no pre-hospital care is given throughout the trip.

As important as first care is the care that should come after the period of hospitalization. It is considered fundamental to rapidly initiate multi-professional rehabilitation activities (16,25). In the present study, the SUS institutions where these activities were carried out were IBR, SARAH and CEPRED. All of these are located in what is known as the wealthy area of the city, at sea level. Due to the fact that the largest part of the affected population usually resides in areas far from these centers, their location represents another obstacle to access. Rehabilitation treatments are by definition slow and lengthy and should be stimuli-intensive. It is imperative for patients to undertake, in some cases, more than one weekly session, and it is therefore also necessary for the family to be involved in the process (13,16,25).

The topography of Salvador, distinctly irregular, may complicate the access to transportation and therefore to travel to rehabilitation institutions for treatment in the post-hospitalization period. In the outskirts of Salvador and especially in the "center," where the terrain is higher than sea level, many houses are built on cliffs and slopes where only steep stairs and paths may facilitate access to public means of transportation.

"Peripheral" places are understood to be those where accessibility essentially depends on roads and means of transportation that make it possible to satisfy and carry out real needs or needs perceived as real (34-37). Hence, we can define "peripheral" as "geographical marginalization" (31). In this way, this study cannot affirm that the inhabitants of these localities do not have effective access to means of transportation, even though while doing fieldwork the existence of physical obstacles that hindered or directly impeded the transportation of patients in search of treatment was observed.

The Nearest Neighbor Hierarchical Clustering method was used for this study, a method whose main disadvantage is that it uses absolute data that can lead to a false idea of risk given that population data is not considered. As was already mentioned, groupings may be generated simply on account of a higher population density in certain regions with greater resources. Other authors (18) highlight yet another disadvantage arising from the existence of a certain degree of arbitrariness, as the minimum number of cases needed to form a cluster is defined by the researcher, who also defines the probabilities to be used. However, it should be emphasized that this descriptive approach facilitates the evaluation of a spatial pattern, offering great advantages for planning and management of resources in public health.
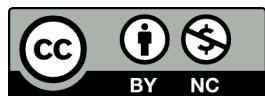
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