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ARTICLE

Spatial reorganization of the Brazilian Unified National Health System's inpatient care supply

Reorganização espacial da provisão de serviços hospitalares do Sistema Único de Saúde

Reordenación espacial de la prestación de servicios hospitalarios en el Sistema Único de Salud brasileño

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Abstract

The joint provision of efficient and equitable healthcare service delivery is a critical factor in improving social welfare. However, healthcare services pose a particular challenge when balancing healthcare provider efficiency and equity. Typically characterized by economies of scale and scope, inpatient care involves a wide variety of medical care that usually demands a broad range of health professional expertise and technological complexity to ensure health care quality. This study analyzes the current spatial organization of the Brazilian general hospitals and their respective flow of patients to identify the possible benefits of closing inefficient hospitals. We studied how inpatient care referrals may be reallocated without increasing access inequities following the potential closure of inefficient public hospitals. We used data from the Brazilian Hospital Information System of the Brazilian Unified National Health System (SIH/SUS) and the Brazilian National Register of Health Establishments (CNES). The smallest and least efficient hospitals were selected as units for potential closure, conditioned on an optimization criterion that minimizes patient travel distances to the nearest efficient hospital. Our results show that there is room for hospital resource reorganization in Brazil without compromising health care access equity.

Health Services Accessibility; Hospital Services; Efficacy; Equity

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Introduction

The joint provision of efficient and equitable health care services delivery is a key factor in improving social welfare [1,2,3,4,5]. However, certain types of health care services pose a particular challenge when seeking to balance health care provision with efficiency and equity. For example, inpatient care, typically characterized by economies of scale and scope, involves a wide variety of medical care that usually demands a broad range of health professional expertise and technological complexity to ensure health care quality. Empirical evidence has already shown that settings in which populations are large enough to allow scale for active learning processes are the most conducive to guaranteeing high quality inpatient care [6]. Population density is also a prerequisite for the cost-effective supply of health specialist teams at large hospitals, where they are more likely to exchange knowledge and follow up on patients, improving overall patient outcomes [4,5]. Therefore, efficient inpatient care provision requires a spatially organized health care supply that considers both the population size and density of its encompassing area.

However, choosing hospital location based solely on principles of efficiency may lead to increased access barriers, especially in remote or rural areas. The spatially organized provision of inpatient care within a network of locally provided health care services at the regional level can attenuate inequities in inpatient care access. Built on the principles of universalization, comprehensiveness, and decentralization, the Brazilian Unified National Health System (SUS) is the largest provider of hospital services in the country [7,8]. Even though all different levels of government (federal, state, and municipal) are responsible for managing, financing, and delivering health care services, Brazil's governmental decentralization delegates the responsibility for guaranteeing health care access to the municipal governments. The local management allows health care needs to be met more easily since health managers are close to the communities that they serve. This proximity often improves health care access and quality, especially concerning primary care [9].

However, these benefits are not evident for secondary and tertiary care across all municipalities. Due to the complexity inherent to the management of these services, their provision is usually only feasible through municipalities. Health Regions are groups of neighboring municipalities defined by the state through the Regionalization Master Plan to allow for the integration, planning, and organization of the healthcare services provision [10]. For each Health Region, health care services networks are designed to be shared by its constituent municipalities. Whitin the region, patient referrals are intended to be regulated and organized following an optimal spatial design that ensures adequate health care access. One issue concerning the institutional design based on Health Regions is that they are not political entities and, as a result, cannot receive fiscal transfers. Empirical evidence has shown that local municipality consortium initiatives have been important in promoting scale and scope economies, increasing population access to specialized health services through patient referral, and avoiding medicine shortage [11]. However, they face obstacles mainly due to management constraints and legal weakness [10,11].

Nevertheless, local governments are encouraged to build and maintain hospitals, since it enhances both funding and political prestige. A large proportion of Brazilian hospitals are small, locally managed, and characterized by low levels of efficiency [7,11,12,13,14,15,16,17].

Carpanez & Malik [17] showed that hospital growth was more intense in Brazil during the 1970s. This expansion was led mainly by philanthropic hospitals with low levels of technology and a small number of beds since, at that time, the demand for inpatient care was more associated with infectious diseases and acute care. Despite the urbanization process and higher prevalence of chronic diseases, the growth of local hospitals after the 1980s followed the same profile as the earliest hospitals. Nowadays, the configuration of these small hospitals is not appropriate to meet the current demand, which requires middle-high complex care. Consequently, these hospitals are marked by low levels of occupancy rates and a large proportion of hospital admissions for ambulatory care-sensitive conditions [17].

Brazil's continental size and the existence of remote areas add another layer of complexity to health care provision and management. Almost half of the Brazilian municipalities have less than 10,000 inhabitants and lack the technical and financial capabilities to manage complex medical facilities, such as hospitals or emergency services [16,18]. Despite their low levels of efficiency, small hospitals are often the only point of access to emergency services in remote areas of Brazil. They also play a key role in emergency health care networks when patients' conditions are time-sensitive [4,5,16], as recently observed during the COVID-19 pandemic [18,19,20].

Previous studies that have analyzed hospital efficiency in Brazil have found that most hospitals are inefficient, especially small hospitals or those managed by municipalities [7,13,14,21,22,23,24]. Amaral [15] focuses on specialized care, examining how to optimize the location of hemodialysis units based on minimum travel distances. Fo & Mota [25] analyzed the optimal location of primary care health units, using the São Paulo Metropolitan Area as a case study. Our study builds on the findings of Amaral [15], Fo & Mota [25], de Almeida Botega et al. [13], and Botega et al. [14], with its efficiency and equity-focused analysis of inpatient care distribution in Brazil. Specifically, we analyze the current spatial organization of hospitals and respective influx of patients to identify the benefits of closing inefficient hospitals. We propose their closure based on minimizing average travel distances from hospitals potentially subject to closure to the nearest efficient hospital with available beds.

Our study differs from Amaral [15] in two major aspects. First, this study examines hospital care in general instead of a particular type of specialized health care service. Second, we minimize the distance traveled by patients considering efficiency scores and bed capacity to relocate and reorganize hospital care in Brazil. In contrast with this study, Fo & Mota [25] address questions of spatial redistribution solely regarding primary care health units. Our study combines the strengths from these two articles (a focus on equity accessibility level and the spatial redistribution of health units), while building upon them with its analysis of how to improve the Brazilian health care system's overall efficiency.

Methods

Data

This paper draws on matched data from two main sources, encompassing the Brazilian National Register of Health Establishments (CNES) [26] and the Brazilian Hospital Information System of the of the SUS (SIH/SUS) [27]. The SIH/SUS is an administrative database that contains records concerning all hospitalizations financed by SUS. We considered all hospitalizations recorded during 2015, excluding long-term hospitalizations, less than 2.5% of total inpatient health care delivered by SUS, and those mostly psychiatric and tuberculosis-related care. The CNES is a national database that gathers mandatory information from all health facilities on a monthly basis for a wide array of indicators, such as capacity or human resources. This study selected July (mid-year) as its temporal reference, since hospital infrastructure does not vary substantially throughout the year. Our sample is comprised of 3,504 Brazilian general hospitals that allocated at least 50% of their beds to SUS and recorded more than 50 hospitalizations throughout 2015, excluding three hospitals with no registered physicians.

Analysis

- **Optimizing inpatient care network efficiency**

An optimization analysis was performed to estimate the shortest distance that patients would need to travel to receive inpatient care at a larger or more efficient hospital. The study utilized patients' average multimodal travel distance as a proxy for equity. Multimodal distance was selected since it considers the complete route traveled by patients and all means of transportation, such as roads, rivers, and air [28]. Patients were considered to have adequate hospital access if their maximum travel distance to an efficient hospital was less than 70km from the origin hospital, corresponding approximately to a one-hour trip [16]. De Almeida Botega et al. [13] estimated hospital technical and scale efficiency scores, which was generously provided by the authors for our study. They considered an input-oriented model with variable returns to scale (VRS) and ran separated models for each group (small hospitals – less than 50 beds, medium hospitals – from 51 to 150 beds, large hospitals – over 150 beds) identified by a cluster analysis to consider minimally homogeneous decision-making units (DMUs). They considered as inputs: (i) human resources working for the SUS (doctors, nurses, nursing assistants, and technicians – standardized by workload hours to allow for hospital comparisons), (ii) SUS infrastructure (number of beds, number of pieces of medium and high-tech medical equipment). For output variables, they considered the number of hospitalizations in five groups based on the International Classification of Disease, 10th revision (ICD-10) (circulatory, respiratory, pregnancy, childbirth/puerperium procedures, and others) and two age groups (younger than 60 and over 60 years old).

Before the optimization process, the Brazilian general hospitals were classified into three groups according to technical efficiency scores, occupancy rates, and the number of beds. The first group, named Closing Hospitals, comprises 497 health units that could potentially be subject to closure. The group was defined by using three criteria: having less than 50 hospital beds, a technical efficiency score below the national average, and an occupancy rate below 70%. The second group of hospitals, named as Unchanging Hospitals, were defined as facilities with occupancy rates above 70% (404 health units). Unchanging Hospitals were characterized by their inability to receive patients from Closing Hospitals due to their already high occupancy rates, in addition to their ineligibility for closure due to the large volume of inpatient care that they provided. The remaining hospitals were named as Receiving Hospitals, which comprised 2,603 hospitals with an occupancy rate below 70% and a mean technical efficiency score above the national average.

The study began by conducting the descriptive analyses of an array of hospital dimensions, encompassing public-private service, productivity, level of procedures, service factors, performance, quality, and geographic coverage. Each dimension's indicators correspond with those used in the literature [7,14]. Subsequently, we performed an optimization analysis based on the previously described hospital classifications, which consisted of minimizing travel distances between Closing Hospitals and the nearest Receiving Hospital based on their maximum capacity. The optimization problem is described below:

$$\text{Minimize} \sum_i \sum_j d_{ij}\, p_{ij} \quad (1.0)$$

where, $i \neq j$

$$\text{Subject to} \sum_j p_{ij} = p_i, \forall i \quad (1.1)$$

$$\sum_j c_j \geq p_{ij} * t_i, \forall i \quad (1.2)$$

in which i stands for a Closing Hospital; j represents a Receiving Hospital; d_{ij} is the distance in km between i and j; p_i is the number of patients hospitalized in i; p_{ij} is the number of patients referred by hospital i to hospital j; c_j is the number of available bed days in j; and t_i is the average stay length in hospital i. Lingo software, version 18.0 (https://lingo.informer.com/) was used to numerically solve the optimization problem.

The study classified potential Closing Hospitals into two groups: those whose patients would need to travel more than 70km to receive care at the nearest Receiving Hospital and those within a 70km range of a potential Receiving Hospital. The latter was designated as eligible for closure without compromising equity in inpatient care access.

- **A comparison of the observed and optimal patient influx from eligible Closing Hospitals**

Following optimization, a comparison was made between the observed patient flow in Closing Hospital municipalities and the optimal patient flow that would be observed if all these patients were to receive care at the nearest Receiving Hospital. To illustrate this comparison, the ratio of optimal patient flow was estimated to all current patient flows for each municipality containing a Closing Hospital. This overlap ratio shows the fraction of total patient flow, from municipalities where the Closing Hospitals were located, who received care at the nearest Receiving Hospital, as designated by the optimization analysis. This indicator shows how optimal patient flows differ from observed flows, which suggests potential room to improve patients' spatial allocation through inpatient care demand management and planning.

The overlap indicator is calculated as follows:

$$Overlap_{ij} = \frac{\text{Number of observed hospitalizations in } j \text{ of individuals living in } i}{\text{Total number of observed hospitalizations of individuals living in } i \text{ in any other municipality}}$$

in which i stands for the Closing Hospital's municipality and j represents the municipality where the optimal Receiving Hospital is located.

For example, if municipality A, which possesses a Closing Hospital with a corresponding Receiving Hospital located in municipality B, presents an overlap of 20%, this means that only 20% of all patients living in municipality A that receive inpatient care outside of their home municipality are receiving inpatient care in municipality B. Instead of going to the nearest municipality (municipality B), the remaining 80% of patients are receiving inpatient care at more distant hospitals. The observed and optimized patient flows for each municipality are plotted in Figure 1, which displays only the most important current flows with more than 10 annual hospitalizations to avoid visual cluttering.

Results

Hospital profile assesment

Table 1 presents the descriptive analyses. Closing Hospitals represent 14% of hospital units (497),which an average of 25 beds, as well as technical and scale efficiency scores of 0.39 and 0.38, respectively. They are also smaller and less efficient than the average Brazilian hospital and perform a relatively small number of hospitalizations, predominantly of moderate complexity. These hospitals usually hospitalize a high proportion of patients (30.63%) for Ambulatory Care Sensitive Conditions (ACSC) [29], which could be avoided with adequate primary care provision or outpatient care delivered at the hospital. Closing Hospitals are mostly managed by local authorities (75%) and have an average occupancy rate as low as 8.53%. Furthermore, extra-municipal residents comprised an average of only 6.46% of Closing Hospitals' patients, suggesting limited patient outreach.

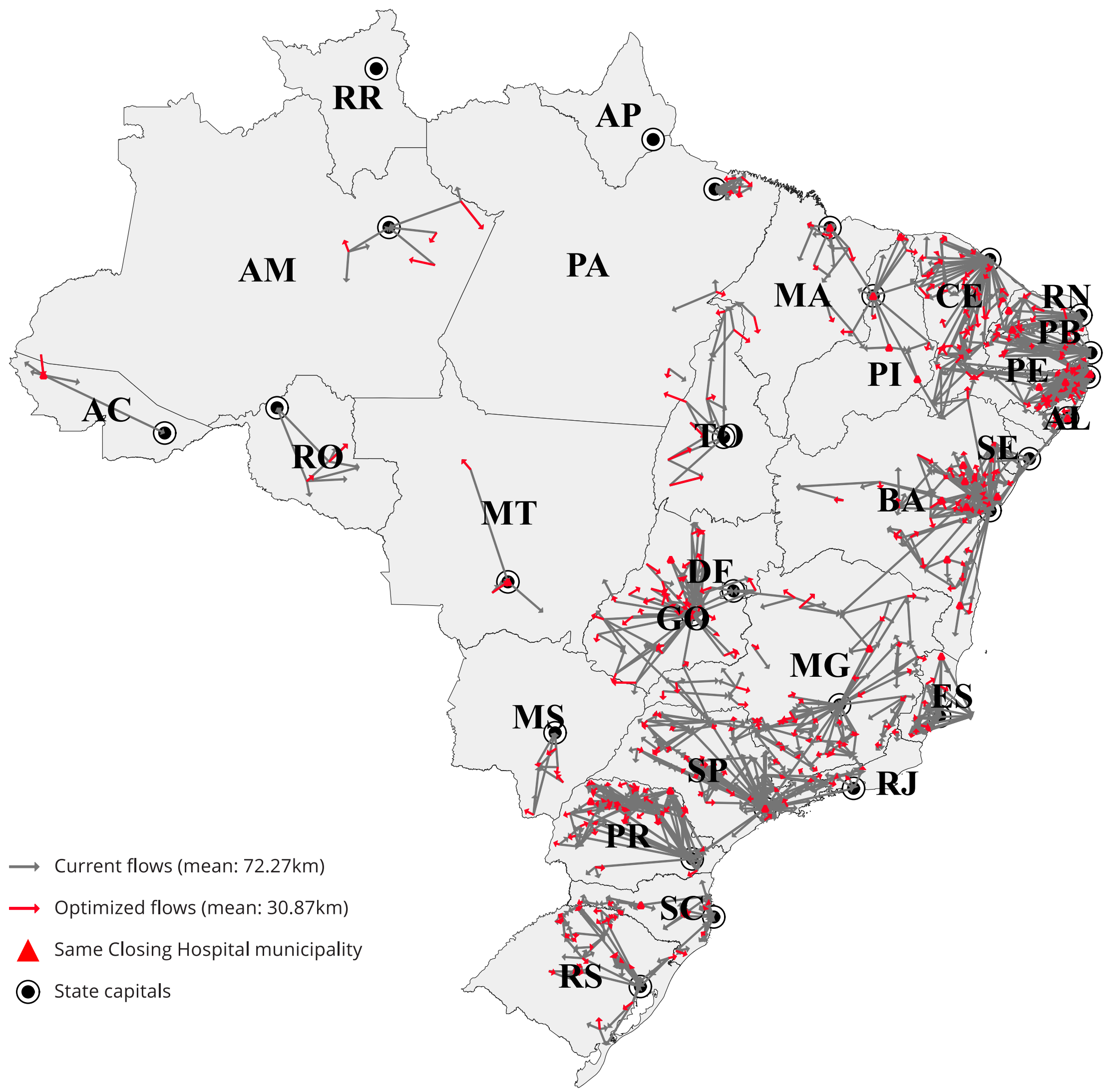
Unchanging Hospitals represent 11% of all hospitals (404 units) and possess a larger average number of beds (181) and higher levels of technical (0.75) and scale (0.93) efficiency than the average Brazilian hospital. Unchanging Hospitals also deliver a substantial volume of care per month (742 hospitalizations, on average), in addition to predominantly high complexity services, which result in higher average occupancy rates (82.45%). Furthermore, they play an essential role in regional health care networks by delivering services to a substantial proportion of non-resident patients (33.32%), who travel an average distance of 332.75km.

Receiving Hospitals (2,603 units) are an intermediate group between Closing and Unchanging Hospitals. They possess higher technical (0.61) and scale (0.79) efficiency than the average Brazilian hospital, but lower technical and scale efficiency than Unchanging Hospitals. Receiving Hospitals have a mean of 63 beds and typically provide a low monthly volume of care (approximately 182 hospitalizations), mostly of medium complexity (98.5%). Furthermore, a high proportion of their patients were hospitalized for ACSC (22.54%), and Receiving Hospitals reported an occupancy rate (31.73%) far below that of Unchanging Hospitals. They receive a significant volume of non-resident patients that travel more than 200km (19.86%), which suggests their importance in regional health care networks. Due to their low occupancy rates, they are able to accommodate potential patients from Closing Hospitals.

Hospital location can affect a hospital's performance and its role within a health care network. For selected attributes of the municipalities where each hospital group is located, we observed that Closing Hospitals are frequently located in municipalities with, in average, low levels of socio-economic development – Human Development Index (HDI) of 0.65 and Gross Domestic Product (GDP) of municipalities per capita of BRL 3,587.90, low population density (78.37 per km^2), and a small number of physicians per 1,000 inhabitants (1.01). Despite their low population density, these municipalities have a higher number of SUS beds per 1,00 inhabitants (2.40) than the Brazilian average (1.72). In contrast, Unchanging Hospitals are located in more developed (HDI of 0.76 and GDP per

Figure 1

Current and simulated flows of patients living in Closing Hospital municipalities. Brazil, 2015.



AC: Acre; AL: Alagoas; AM: Amazonas; AP: Amapá; BA: Bahia; CE: Ceará; DF: Distrito Federal; ES: Espírito Santo; GO: Goiás; MA: Maranhão; MG: Minas Gerais; MS: Mato Grosso do Sul; MT: Mato Grosso; PA: Pará; PB: Paraíba; PE: Pernambuco; PI: Piauí; PR: Paraná; RJ: Rio de Janeiro; RN: Rio Grande do Norte; RO: Rondônia; RR: Roraima; RS: Rio Grande do Sul; SC: Santa Catarina; SE: Sergipe; SP: São Paulo; TO: Tocantins.
Source: Brazilian Health Informatics Department [26,27].
Note: gray arrows represent referral flows of at least 10 hospitalizations.

capita of BRL 7,779.92) and more populated (1,954.05 per km^2) municipalities with a greater supply of physicians (1.44 per 1,000 inhabitants). Municipalities with Receiving Hospitals are located in an intermediate position in terms of the indicators analyzed.

Our results suggest that locally relocating patients from Closing Hospitals could improve hospital sector efficiency. However, it is essential to assess the risks regarding whether these hospital closures could decrease adequate health care access. As a result, the subsequent section explores potential efficiency benefits from reorganizing Brazilian hospital networks utilizing an equity-focused optimization analysis.

Table 1

Descriptive statistics of Closing, Receiving, and Unchanging Hospitals. Brazil, 2015.

	Closing Hospitals	**Receiving Hospitals**	**Unchanging Hospitals**		**All hospitals**
Number of hospitals	497	2603	404		3,504
Percentage of hospitals	14.18	74.29	11.53		
	%	**%**	**%**		**%**
Provider type					
Local public	70.02	35.38	22.03		38.76
State public	5.03	9.49	35.40		11.84
Federal public	-	1.15	3.71		1.28
Private	7.85	18.71	7.43		15.87
Philanthropic	17.10	35.23	31.44		32.22
Labor union	-	0.04	-		0.03
Total	100.00	100.00	100.00		100.00
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**p-value**	**Mean (SD)**
Efficiency					
Technical efficiency	0.39 (0.11)	0.61 (0.22)	0.75 (0.19)	< 0.001	0.59 (0.23)
Scale efficiency	0.38 (0.14)	0.79 (0.22)	0.93 (0.10)	< 0.001	0.75 (0.25)
Dimensions/Indicators					
Public-private services					
Number of SUS beds	24.94 (8.99)	62.82 (78.16)	181.37 (147.99)	< 0.001	71.12 (93.94)
SUS beds (%)	96.03 (9.60)	88.78 (13.61)	88.31 (13.64)	< 0.001	89.76 (13.36)
Productivity					
Monthly volume of care provided	19.83 (11.31)	181.57 (240.70)	741.70 (531.51)	< 0.001	223.21 (337.21)
Level of procedures					
Medium complexity procedures (%)	99.84 (2.82)	98.50 (6.76)	93.14 (11.01)	< 0.001	98.07 (7.24)
High complexity procedures (%)	0.16 (2.82)	1.50 (6.76)	6.86 (11.01)	< 0.001	1.93 (7.24)
Hospitalization rate due to ambulatory care sensitive conditions (%)	30.63 (14.91)	22.54 (14.12)	12.43 (8.79)	< 0.001	22.53 (14.48)
Service factors					
Physicians per bed (standardized)	0.51 (0.40)	0.97 (2.81)	2.53 (1.81)	< 0.001	1.08 (2.56)
Nurses per bed (standardized)	0.15 (0.10)	0.19 (0.31)	0.45 (0.31)	< 0.001	0.22 (0.30)
Nursing assistants and technicians per bed (standardized)	0.50 (0.28)	0.74 (0.77)	1.55 (1.00)	< 0.001	0.80 (0.80)
Senior management professionals per bed (standardized)	0.05 (0.04)	0.04 (0.08)	0.03 (0.06)	< 0.001	0.04 (0.07)
Medium complexity technology employed per bed	0.48 (0.46)	0.46 (0.57)	0.35 (0.81)	0.0014	0.45 (0.59)
High complexity technology employed per bed	0.04 (0.23)	0.31 (0.91)	1.57 (1.51)	< 0.001	0.41 (1.03)
Hospitalization expenses (standardized) (USD/hospitalization)	126.56 (35.39)	202.20 (206.62)	422.86 (268.58)	< 0.001	216.92 (215.40)
Performance					
Average length of stay (days)	3.24 (1.31)	3.79 (2.45)	6.42 (2.97)	< 0.001	4.02 (2.55)
Bed turnover rate	0.74 (0.47)	2.06 (1.45)	1.89 (1.93)	< 0.001	1.86 (1.49)
Occupancy rate (%)	8.53 (5.23)	31.73 (17.17)	82.45 (11.39)	< 0.001	34.29 (24.58)

(continues)

Table 1 (continued)

	Mean (SD)	Mean (SD)	Mean (SD)	p-value	Mean (SD)
Quality					
Crude mortality rate (%) (standardized)	1.88 (2.48)	3.09 (3.39)	7.19 (4.24)	< 0.001	3.39 (3.68)
Hospital transfers (%)	4.91 (6.60)	3.47 (4.37)	3.73 (4.92)	< 0.001	3.70 (4.83)
Geographic coverage					
Non-resident care (%)	6.46 (11.76)	19.86 (28.27)	33.32 (21.60)	< 0.001	19.51 (26.70)
Average distance traveled by SUS patients (km)	125.17 (207.71)	214.27 (209.80)	332.75 (204.68)	< 0.001	215.29 (215.33)

SUS: Brazilian Unified National Health System.

Sources: Brazilian Health Informatics Department [26,27], Brazilian Central Bank [36].

Optimization analysis

The optimization results show that 419 of the 497 Closing Hospitals (about 85%) are within a 70km radius of a Receiving Hospital and, therefore, are eligible for closure without significantly impacting inpatient care access equity. Figure 2 displays all 497 potential Closing Hospitals. Blue dots (78 units) represent hospitals that cannot be closed since their patients would have to travel more than 70km to the nearest Receiving Hospital following their closure. Red dots represent hospitals that would be subject to closure in accordance with the study's optimization analysis. As shown in Figure 2, red dots are mostly concentrated along the Brazilian coast or close to urban areas, while blue dots are mostly located in remote or rural parts of the Central-West, North, and Northeast regions, further away from major cities.

The largest distances between Closing Hospitals and Receiving Hospitals are concentrated in the states of the North Region, which contains some of the least developed and most remote areas in Brazil. Patients in the states of Amapá and Roraima would have to travel, on average, more than 300km to receive inpatient care if inefficient hospitals were to be closed.

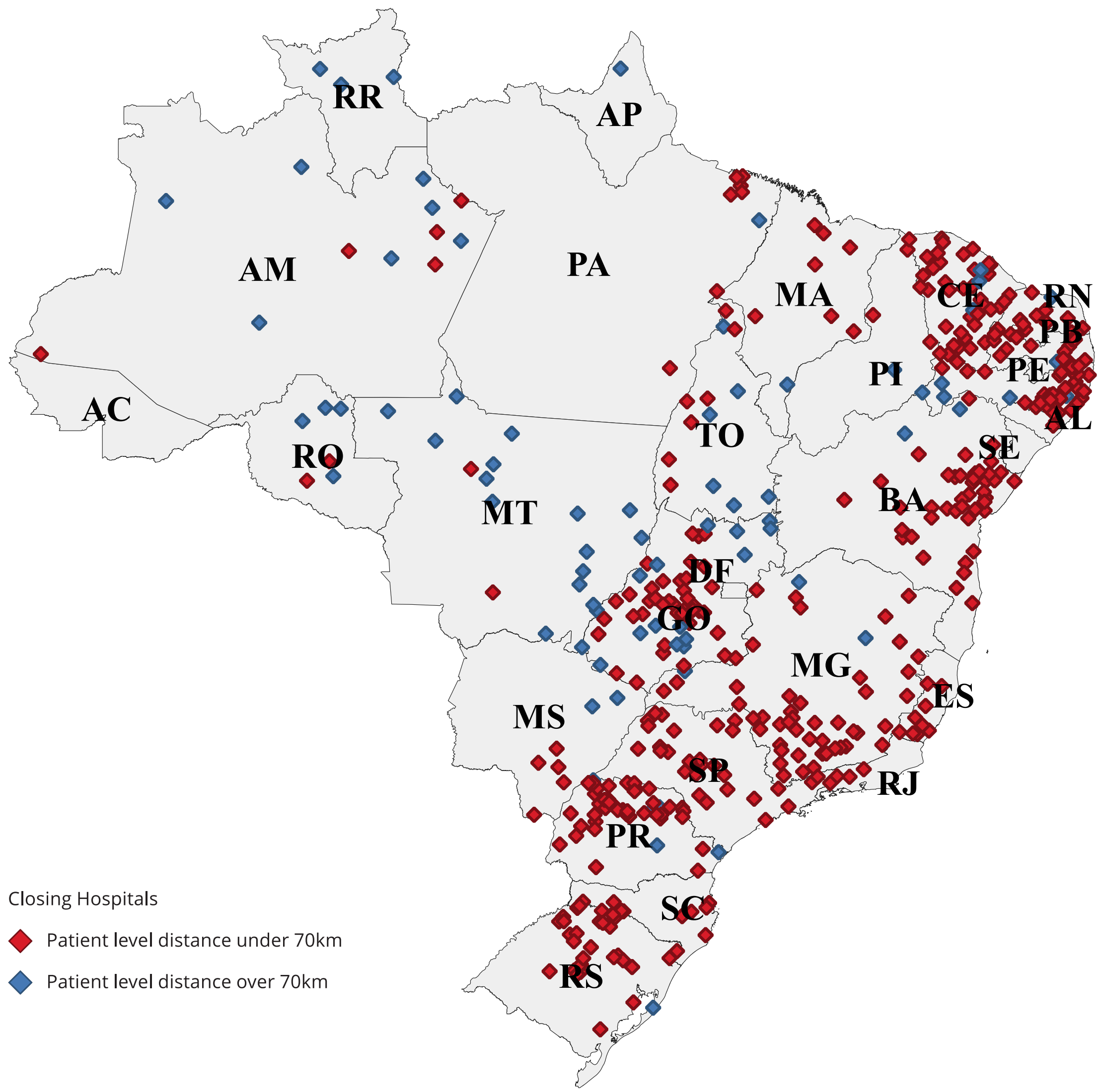
For most of the 419 hospitals considered eligible for closure, the corresponding Receiving Hospital presented higher levels of technical (78.76%) and scale (90.45%) efficiency. Only 40 (9.55%) of the Receiving Hospital presented a technical efficiency more than 10% lower than the hospital subject to potential closure that they corresponded to (Table 2). However, patient referrals from the 419 Closing Hospitals could also affect the technical and scale efficiency of the corresponding Receiving Hospitals. For example, the corresponding Receiving Hospitals' occupancy rates would increase from an average of 31.73% to 32.6%. The small, predicted impact on Receiving Hhospitals' occupancy rates is a result of the low volume of hospitalizations (98,192) at the Closing Hospitals, which possess only 1.26% of the total number of hospital beds in Brazil. These results emphasize the potential efficiency gains from closing small and inefficient hospitals in Brazil.

Another important aspect of potential hospital closure concerns how they could affect patient travel distances. Our simulations suggest that patients from the 419 Closing Hospitals would travel an additional 29km on average. States in the North Region displayed largest increases in average patient travel distance, recording an increase of approximately 45km.

Figures 1 and 3 show the observed and simulated patient flows from Closing Hospital municipalities. The gray lines represent the most important current patient referral flows from municipalities where Closing Hospitals are located to municipalities where inpatient care is delivered. These flows include patients that received care at Closing Hospitals, as well as patients that received care in other municipalities. The study observed patient flows to receive care in other municipalities even when local Closing Hospitals were available. In this regard, only 8% of the total number of patients living in the municipalities where the 419 Closing Hospitals were located received care at these hospitals. The red lines represent the simulated patient flows following the closure of the 419 Closing Hospitals. While most current patient flows (gray arrows) point to state capitals, simulated patient flows following hospital closures (red arrows) typically point to more closely located Receiving Hospitals.

Figure 2

Closing Hospital locations based upon average patient travel distance (over or under 70km) by Brazilian state, 2015.



AC: Acre; AL: Alagoas; AM: Amazonas; AP: Amapá; BA: Bahia; CE: Ceará; DF: Distrito Federal; ES: Espírito Santo; GO: Goiás; MA: Maranhão; MG: Minas Gerais; MS: Mato Grosso do Sul; MT: Mato Grosso; PA: Pará; PB: Paraíba; PE: Pernambuco; PI: Piauí; PR: Paraná; RJ: Rio de Janeiro; RN: Rio Grande do Norte; RO: Rondônia; RR: Roraima; RS: Rio Grande do Sul; SC: Santa Catarina; SE: Sergipe; SP: São Paulo; TO: Tocantins.
Source: Brazilian Health Informatics Department [26,27].

This suggests that many patients from Closing Hospital municipalities could end up traveling shorter distances, improving access to inpatient care.

Figure 3 shows both current and simulated patient flows for selected states. For example, in the State of Amazonas, there are four hospitals eligible for closure located in the municipalities of Guajará, Nhamundá, Nova Olinda do Norte, and Silves. In three of these municipalities, patients who currently travel to other municipalities to receive care could significantly shorten their travel distances under the optimized health care provision scenario, resulting in shorter travel distances for patients

Table 2

The number of Closing Hospitals and patients categorized by efficiency score differences between corresponding pairs of Closing and Receiving Hospitals following inpatient care supply optimization. Brazil, 2015.

Efficiency	Receiving Hospitals	Closing Hospitals n (%)	Patients n
Technical			
More efficient	Over 10%	271 (64.68)	64,313
	Up to 10%	59 (14.08)	14,117
Less efficient	Over 10%	49 (11.69)	12,527
	Up to 10%	40 (9.55)	7,235
Scale			
More efficient	Over 10%	357 (85.20)	80,815
	Up to 10%	22 (5.25)	5,160
Less efficient	Over 10%	8 (1.91)	1,829
	Up to 10%	32 (7.64)	10,388

Source: Brazilian Health Informatics Department [26,27].

and reduced pressure on certain hospital units. Notably, current patient flows (gray arrows) indicate that the most important flows are toward the State capital of Manaus.

In Acre, there is only one hospital eligible for closure, located in the Municipality of Cruzeiro do Sul. In 2015, Cruzeiro do Sul has two hospitals, including one Closing Hospital (20 beds) and one Receiving Hospital (34 beds). Despite having two hospitals, patients from Cruzeiro do Sul frequently sought care at hospitals in other municipalities, particularly Mâncio Lima, Rodrigues Alves, Tarauacá, and Rio Branco (the state capital). If patient flows were redirected in accordance with the optimization scenario, nearly all patients could receive care in their municipality of residence, reducing travel distances to virtually zero in this case. Similar patterns can be observed in other Brazilian regions, as portrayed in Figure 3.

The average overlap indicator was estimated using the ratio of optimized patient flows to current patient flows for Closing Hospital municipalities. For Brazil as a whole, only 17.45% of hospitalizations of residents from Closing Hospital municipalities occurred at the optimal Receiving Hospital. Conversely, most patients were referred to more distant cities, usually state capitals. The average overlap indicator varies by state, with Acre demonstrating the highest overlap (94.98%), followed by Mato Grosso (52.85%) and Piauí (51.89%). However, opposing trends are witnessed in Amapá and Roraima, where no patients received care at the optimal Receiving Hospital.

Discussion

This paper is the first attempt to analyze the Brazilian hospital provision from a perspective that considers both efficiency and equity. We studied how to reallocate inpatient care referrals without increasing access inequities following the potential closure of inefficient public hospitals. Our findings show that there is room to increase Brazilian hospital's efficiency without compromising equitable access to inpatient care. Among the 497 inefficient hospitals, the study recommends against closing 78 hospitals of which the patients would need to travel more than 70km to reach the nearest Receiving Hospital, likely increasing inequity in inpatient care access. Hospitals eligible for closure were typically small, inefficient, and possessed low occupancy rates. In addition, they provided only 0.9% of total hospitalizations and represented only 1.26% of the total supply of hospital beds in Brazil. Furthermore, the closure of inefficient hospitals will likely result in greater patient referrals to more efficient hospitals.

Figure 3

Current and optimized flows of patients living in Closing Hospital municipalities for selected Brazilian states, 2015.

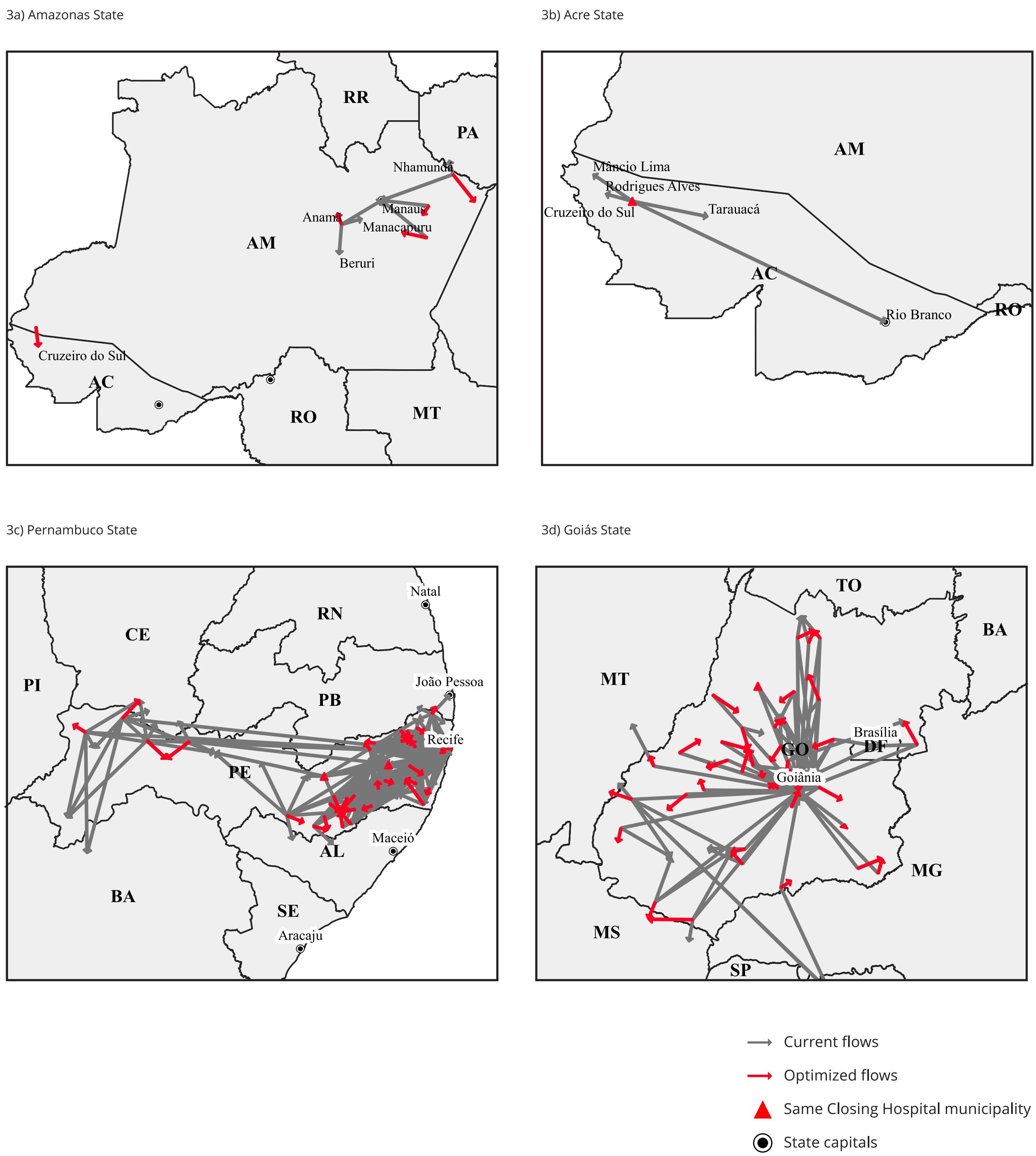


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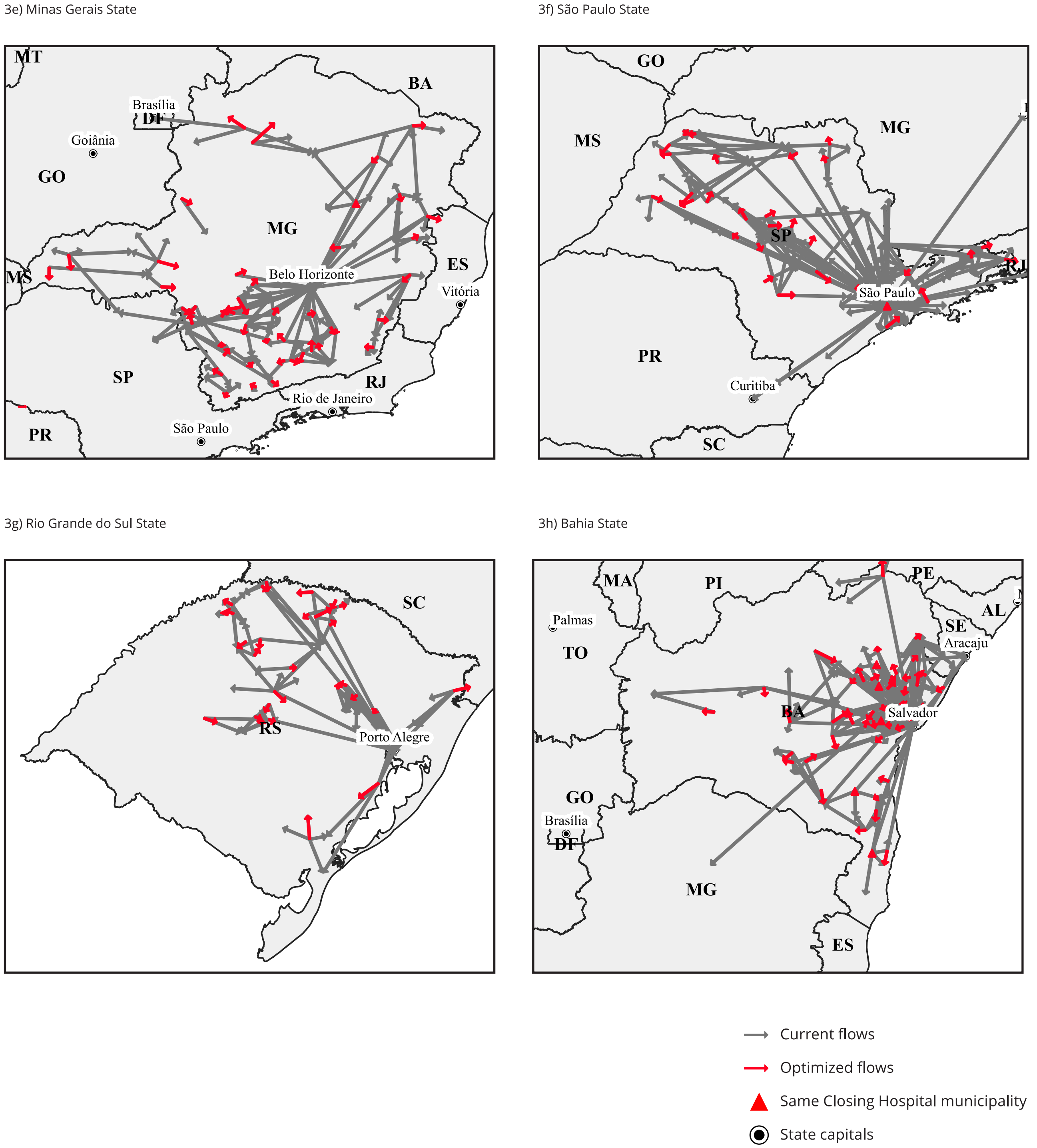
Figure 3 (continued)



AC: Acre; AL: Alagoas; AM: Amazonas; AP: Amapá; BA: Bahia; CE: Ceará; DF: Distrito Federal; ES: Espírito Santo; GO: Goiás; MA: Maranhão; MG: Minas Gerais; MS: Mato Grosso do Sul; MT: Mato Grosso; PA: Pará; PB: Paraíba; PE: Pernambuco; PI: Piauí; PR: Paraná; RJ: Rio de Janeiro; RN: Rio Grande do Norte; RO: Rondônia; RR: Roraima; RS: Rio Grande do Sul; SC: Santa Catarina; SE: Sergipe; SP: São Paulo; TO: Tocantins.
Source: Brazilian Health Informatics Department [26,27].

The closure of inefficient medical establishments has already been analyzed by earlier studies [3,30,31,32]. Capps et al. [32] used a comparable approach, estimating social welfare changes in terms of cost and access that would result from the closure of inefficient hospitals in the United States. In general, they found that closing inefficient hospitals in urban areas would increase aggregate social welfare. Their simulation considered the effects of closing inefficient hospitals on patient travel distances, finding minor effects on inpatient care access since inefficient urban hospitals are usually close to other hospitals. Our study utilized a 70km threshold as the maximum acceptable distance for patient travel following inefficient hospital closures. As previously shown, in more dense urban areas, like the Southeast and South regions, increased patient travel distances are not likely to significantly affect inpatient care.

Moreover, Deily et al. [3] estimated how relative inefficiency and hospital ownership type (for-profit, non-profit, and government-owned) affected the probability of hospitals exiting the inpatient services market in the United States. Their results show that relative inefficiency plays an important role in explaining the exit of for-profit and non-profit hospitals from the inpatient service market but is not associated with the exit of government-owned hospitals. Deily et al.'s [3] results are in line with Ciliberto & Lindrooth's [31] findings, who also examined exits from the hospital industry, reporting that inefficient hospitals were likely to exit first. In our study, most Closing Hospitals were government-owned units managed by local municipalities and possessed lower levels of technical efficiency [13]. Despite their low efficiency levels, these hospitals are unlikely to exit the hospital industry, as decisions regarding government-owned hospitals are typically political in nature rather than resulting from market competition. Some authors suggest that financial and political incentives explain the persistence of local hospitals with low efficiency and poor patient care outcomes [7,11,12,33]. In Brazil, hospitals often receive financial incentives in the form of fiscal transfers from the federal government to municipalities to fund hospitalizations based on utilization.

Hospital closures may also have important long-run implications for industry efficiency. Lindrooth et al. [30] assessed how the closure of urban hospitals in the United States affected industry efficiency, finding that the Closing Hospitals were smaller and less efficient than their competitors. In turn, closing inefficient hospitals resulted in a decrease in costs per adjusted admission at nearby hospitals, mainly due the increased utilization of previously empty beds. Similar to our study, Lindrooth et al. [30] also considered access issues by examining the effects of urban hospital closures on neighboring hospitals within a 5 mile (8.05km) radius. However, in contrast with Lindrooth et al.'s [30] analysis, this study did not assess the effects on potential Receiving Hospitals, although we would expect to witness overall efficiency improvements since these hospitals are likely to experience increased occupancy rates.

Additionally, our study estimated an overlap indicator to express the ratio of current patient flow from municipalities with inefficient hospitals to the optimal Receiving Hospital in comparison with patient flow to other non-optimal hospitals. This analysis revealed that most patients from inefficient hospitals were traveling longer distances to receive inpatient care, often to larger hospitals in the state capitals. This finding highlights the potential technical/efficiency scale and welfare gains that could result from the spatial reorganization of patient referrals. However, some potential caveats must be considered [34]. First, there must be political consequences after hospitals' closure since local governments have incentives to maintain hospitals despite their low efficiency and resolution. Municipalities manage 70% of Closing Hospitals, so the Brazilian Ministry of Health should implement an incentives policy to guarantee the closure of these hospitals. Second, a better regulation system of patient referral is also necessary. Some Brazilian states, such as Minas Gerais and Santa Catarina, already established a unified regulation center that controls all referrals among healthcare establishments. This center allows for shorter waiting times and better allocation of patients in the healthcare network. Third, the closure of hospitals would require the availability of sanitary transportation system, guaranteeing adequate conditions for patients' transfer that prevent deepening access inequalities.

This study possesses certain limitations. First, the optimization analyses assumed that Receiving Hospitals could provide all medium complexity health care services. We used hospital records to infer the type of care delivered by each hospital without considering patient outcomes. Although the CNES provides information regarding health care equipment, these data may not reflect reality. Some equipment may not be in working order or facilities may lack adequate personnel to operate certain types of health care equipment. Second, our analysis did not consider variations in hospital staff training, estimating a hospital's availability to receive additional patients solely based upon occupancy rates. However, many hospitals with empty beds might also lack an adequate team of health care professionals necessary to increase hospital capacity. Third, Brazilian databases do not provide enough data to assess differences in the quality of care provided by hospitals, so efficiency scores were unable to consider health care quality. Fourth, the study has not considered differences regarding road condition and patient characteristics (age, health condition, special needs).

Despite these limitations, this study makes several important contributions. First, our analysis outlines opportunities to better allocate Brazilian health care resources to optimal Receiving Hospitals, while also identifying inefficient hospitals that could be closed without impacting health care equity accessibility level. These results could assist in the construction of regional health care services networks in Brazil, as most low-performing hospitals are located close to more efficient ones. Furthermore, our results reinforce the importance of centralized health care provision regulation in guaranteeing better access to health care services. Our findings showed that most patients traveled to medical facilities located further away than the corresponding optimal Receiving Hospital. This is particularly important in the Brazilian context, since local governments may be granted incentives discouraging the optimal spatial allocation of inpatient care.

Hospital reorganization is a crucial factor to the financial sustainability of the Brazilian health care system. It is important to foster hospital networks based upon economies of scale and scope, knowledge exchange, active learning, and benefits related to centralized health care management and coordination [11]. This study provides a useful instrument of analysis to support the monitoring and management of the Brazilian hospital sector. However, it is essential that future studies consider additional issues – such as patient transportation logistics, hospital spending, and alternate methods, applying weighting schemes in specific localities, depending on the context (remote and rural areas, elderly people, patient with a critical health condition) [35]. Finally, we would recommend that future research build upon this study's findings by estimating the potential savings and efficiency improvements that would result from the hospital reorganization detailed by this study.

Conclusion

This paper analyzed the current spatial organization of general hospitals and their flows of patients to identify the benefits of closing inefficient hospitals in Brazil. Our main findings suggest that there are opportunities to increase Brazilian hospital efficiency without compromising equitable access to inpatient care by optimizing the spatial allocation of inpatient care. However, the Health Ministry should launch health policies to encourage state governments to implement a unified regulation system and sanitary transportation. These policies are essential for the better allocation of patients and resources.

Contributors

L. A. Botega contributed to study conception and design, data acquisition, analysis, and interpretation, and writing and review of the text. M. V. Andrade and G. R. Guedes contributed to the data analysis and interpretation and review of the text. D. Nogueira contributed to the optimization estimation, data analysis and interpretation, and review of the text. All the authors approved the final version to be published.

Additional informations

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Resumo

A promoção conjunta da prestação eficiente e justa dos serviços de saúde é essencial para melhorar o bem-estar social. No entanto, equilibrar eficiência e equidade entre os prestadores de serviços de saúde é um desafio. Normalmente caracterizado por economias de escala e escopo, o atendimento hospitalar envolve diversos serviços médicos que geralmente exigem ampla especialização profissional em saúde e complexidade tecnológica para garantir a qualidade da assistência médica. Este estudo analisa a atual organização espacial dos hospitais gerais brasileiros e seus respectivos fluxos de pacientes para identificar ganhos decorrentes do fechamento de hospitais ineficientes. Estudamos como realocar encaminhamentos de internação hospitalar sem aumentar as iniquidades de acesso à saúde após o possível fechamento de hospitais públicos ineficientes. Utilizamos dados obtidos do Sistema de Informações Hospitalares do Sistema Único de Saúde (SIH/SUS) e do Cadastro Nacional de Estabelecimentos de Saúde (CNES). Os hospitais menores e menos eficientes foram selecionados como unidades de potencial fechamento, condicionados a um critério de otimização que minimiza as distâncias de viagem dos pacientes até o hospital mais eficiente. Nossos resultados mostram que há espaço para reorganizar recursos hospitalares no Brasil sem comprometer a equidade no acesso aos serviços de saúde.

Acesso aos Serviços de Saúde; Serviços Hospitalares; Eficiência; Equidade

Resumen

La promoción conjunta de la prestación eficiente y justa de los servicios de salud es fundamental en la mejora del bienestar social. Sin embargo, es un reto para el área equilibrar la eficiencia y la equidad entre los proveedores de servicios de salud. La atención hospitalaria, caracterizada en general por economías de escala y alcance, se compone de varios servicios médicos que requieren muchas veces especialización profesional en salud y complejidad tecnológica para garantizar la calidad de la atención médica. Este estudio analiza la organización espacial actual de los hospitales generales brasileños y sus respectivos flujos de pacientes para identificar las mejorias resultantes del cierre de hospitales ineficientes. Se examina cómo reasignar las derivaciones de hospitalización sin aumentar las inequidades en el acceso a la salud tras el posible cierre de los hospitales públicos ineficientes. Los datos se obtuvieron del Sistema de Información Hospitalaria del Sistema Único de Salud (SIH/SUS) y del Registro Nacional de Establecimientos de Salud (CNES). Se seleccionaron los hospitales pequeños y menos eficientes como potenciales unidades de cierre bajo el criterio de optimización que minimiza las distancias de traslado de los pacientes al hospital más eficiente. Los resultados mostraron que existe un espacio para reorganizar los recursos hospitalarios en Brasil sin comprometer el acceso a la salud.

Accesibilidad a los Servicios de Salud; Servicios Hospitalarios; Eficiencia; Equidad

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