The Use of Tomographs in Brazil's National Health System: An Analysis of the Effectiveness of the Public Network in Rio Grande do Norte

Tiago de Oliveira Barreto, Elinaldo Bernardo de Oliveira Júnior, Israel José dos Santos Felipe, Jordana Crislayne de Lima Paiva, Nicolas Vinicius Rodrigues Veras, Lorena de Macedo Silva, João Maria Macedo da Costa, Érika Santos de Aragão, Thaísa Góis Farias de Moura Santos Lima, Célio da Costa Barro, Rafael Silveira e Silva, Fernando Rocha de Andrade, Pablo Holanda Cardoso, Andréa Santos Pinheiro, Guilherme Medeiros Machado, Claudia Maria Miranda Veloso, Luciana Simões Camara Leão, Karilany Dantas Coutinho, Ricardo Alexsandro de Medeiros Valentim

Table of Contents

The Use of Tomographs in Brazil's National Health System: An Analysis of the Effectiveness of the Public Network in Rio Grande do Norte

Tiago de Oliveira Barreto[1] PhD; Elinaldo Bernardo de Oliveira Júnior[1]; Israel José dos Santos Felipe[1] PhD; Jordana Crislayne de Lima Paiva[1] MD; Nicolas Vinicius Rodrigues Veras[1] PhD; Lorena de Macedo Silva[1]; João Maria Macedo da Costa[1]; Érika Santos de Aragão[2] PhD; Thaísa Góis Farias de Moura Santos Lima[1] PhD; Célio da Costa Barro[3] MD; Rafael Silveira e Silva[4] PhD; Fernando Rocha de Andrade[5] MD; Pablo Holanda Cardoso[1] PhD; Andréa Santos Pinheiro[1] MD; Guilherme Medeiros Machado[6] PhD; Claudia Maria Miranda Veloso[7] PhD; Luciana Simões Camara Leão[8]; Karilany Dantas Coutinho[1] PhD; Ricardo Alexsandro de Medeiros Valentim[1] PhD

[1] Federal University of Rio Grande do Norte (UFRN), Laboratory of Technological Innovation in Health (LAIS) Natal BR
[2] Federal University of Bahia (UFBA) Salvador BR
[3] Federal Court of Auditors Natal BR
[4] Federal Court of Auditors, Brazilian Institute of Education, Development and Research (IDP) Brasília BR
[5] Federal Public Ministry, Public Prosecutor's Office in Rio Grande do Norte (PGR) Natal BR
[6] LyRIDS, ECE-Engineering School Paris FR
[7] University of Aveiro, Center for Global Studies (ESTGA), Research Unit in Governance, Competitiveness and Public Polices (GOVCOPP) Aveiro PT
[8] Ministry of Health, Secretariat of Science, Technology and Innovation Brasília BR

Corresponding Author:
Tiago de Oliveira Barreto PhD

Federal University of Rio Grande do Norte (UFRN), Laboratory of Technological Innovation in Health (LAIS)
Av. Nilo Peçanha, 620 - Petrópolis, Natal - RN
Natal
BR

Abstract

Background: The evaluation of health technologies is fundamental to the sustainability of the Brazilian National Health System (SUS), especially in highly complex and costly procedures such as computed tomography.

Objective: This study analyzed the financial efficiency of CT scanner use in the SUS in the state of Rio Grande do Norte (Brazil), considering the distribution of supply, the profile of providers, and the idle capacity of the public network.

Methods: A total of 49,061 CT scan requests registered in the state system "RegulaRN Ambulatorial" between October 2023 and January 2025 were examined. Subsequently, data cleaning and grouping were performed

Results: The results indicated that 66.8% of requests were from oncology patients, 61.2% of whom were female, predominantly from municipalities with higher population densities, such as Natal and Mossoró, with an average waiting time of 44 days. More than 99% of the exams were performed by private and philanthropic hospitals contracted by SUS, while public units with CT scanners accounted for less than 1% of production, evidencing significant underutilization.

Conclusions: The findings suggest that strategically shifting demand to the public health system can increase efficiency, reduce costs and waiting times, and promote greater equity in access, contributing empirical evidence for more rational public policies on the use of diagnostic technologies. Clinical Trial: N/A

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?
✓ **Please make my preprint PDF available to anyone at any time (recommended).**

Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✔ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**

Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v

Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

No. Please do not make my accepted manuscript PDF available to anyone. I understand that if I later pay to participate in <a href="https:/

Original Manuscript

Original Paper

The Use of Tomographs in Brazil's National Health System: An Analysis of the Effectiveness of the Public Network in Rio Grande do Norte

Abstract

Background: The evaluation of health technologies is fundamental to the sustainability of the Brazilian National Health System (SUS), especially in highly complex and costly procedures such as computed tomography. **Objective:** This study analyzed the financial efficiency of CT scanner use in the SUS in the state of Rio Grande do Norte (Brazil), considering the distribution of supply, the profile of providers, and the idle capacity of the public network. **Methods:** A total of 49,061 CT scan requests registered in the state system "RegulaRN Ambulatorial" between October 2023 and January 2025 were examined. Subsequently, data cleaning and grouping were performed. **Results**: The results indicated that 66.8% of requests were from oncology patients, 61.2% of whom were female, predominantly from municipalities with higher population densities, such as Natal and Mossoró, with an average waiting time of 44 days. More than 99% of the exams were performed by private and philanthropic hospitals contracted by SUS, while public units with CT scanners accounted for less than 1% of production, evidencing significant underutilization. **Conclusions:** The findings suggest that strategically shifting demand to the public health system can increase efficiency, reduce costs and waiting times, and promote greater equity in access, contributing empirical evidence for more rational public policies on the use of diagnostic technologies.

Keywords: Health Economics. RegulaRN Ambulatorial. Computed tomography. Health Regulation. Public Health.

Introduction

Efficiency in public health management is a central and recurring theme in discussions about the sustainability of health systems and the quality of services offered to the population. In Brazil, the Brazilian National Health System (SUS) represents a universal and free model, designed to ensure the constitutional right to health. However, this system faces significant challenges due to the scarcity of financial resources and the constant growth in demand for services, circumstances that intensify the need for rational and efficient allocation of available resources to ensure equity in access and quality of care provided [1-5].

Within the context of health economics, analyzing the costs related to the state apparatus, as well as monitoring the investment scenario, is essential to promoting efficiency in access to public health [6]. Due to Brazil's continental size (approximately 8,510,000 km²) and significant population (more than 212 million inhabitants), the country invests billions of Brazilian reais in public health, approximately 3.88% of the federal budget, which leads us to question whether the amount is poorly distributed. When compared to Organisation for Economic Co-operation and Development (OECD) countries, even though Brazil does not belong to this organization, it ranks among those that invest the least in public health, and a large portion of the population depends on services offered by the private sector. This is because, of the 9.8% of GDP invested, 60% is private [7-9].

Promoting health monitoring through Digital Health systems can help to address the greatest weaknesses in the public health system [10,11]. One of the important topics for monitoring is the performance of consultations and examinations, especially highly complex examinations. In this sense, computed tomography is a fundamental clinical procedure for the diagnosis of various diseases, constituting an essential step in many care flows [12]. However, the uneven distribution of this equipment and the variation in the degree of utilization among service providers can compromise both access and the efficiency of the system. To this end, health systems increasingly need timely and efficient regulatory systems.

Recent Brazilian studies highlight regional disparities in the supply and use of CT scanners in the SUS, as well as pointing out challenges related to production capacity and the allocation of technological resources. Research such as that conducted by Santos [13] and Santos et al. [14] discusses the availability and degree of use of CT scanners, while investigations carried out by Dovales *et al.* [15] and Viacava *et al.* [16] address issues related to the distribution of resources and the quality of services, which reinforces the urgent need to optimize the use of this equipment in the face of budget constraints and constantly increasing demand.

RegulaRN Ambulatorial is the current system responsible for managing outpatient healthcare services in Rio Grande do Norte (RN). This digital health system is responsible for coordinating and systematizing requests for tests, while organizing the queues for procedures offered by the SUS. This article analyzes requests for computed tomography exams, investigating the execution of this type of procedure for the evaluation of the efficiency of public resource use, in addition to identifying possible regional disparities, efficiency, and effectiveness in the procedures and services provided [17-19]. The RegulaRN Ambulatorial and the different types of exams incorporated by the platform is used for the analysis presented in the results section.

Given this scenario, the study begins with the following question: what does the cost-effectiveness analysis of CT scanners in the SUS (Unified Health System) in Rio Grande do Norte reveal: efficiency or waste? In this context, efficiency is understood as the use of equipment to maximize access and clinical outcomes with available resources. Waste, on the other hand, occurs when there is underutilization or inadequate allocation of equipment and resources. The objective is to analyze the use of CT scanners in the public health system of Rio Grande do Norte, assess the effectiveness of the service, the distribution of supply, the profile of providers, and the adequacy of allocated resources. The relevance of the research lies in providing support for improving the efficiency of public health management in the state of Rio Grande do Norte and proposing strategies that can be replicated in other national or international contexts.

## Sociodemographics and regional health mapping of Rio Grande do Norte

Rio Grande do Norte (RN) is a state located in the Northeast region of Brazil, characterized by its socioeconomic and demographic diversity. According to data from the Brazilian Institute of Geography and Statistics [20]. It has approximately 3.3 million inhabitants spread across 167 municipalities and occupies a land area of 52,811 km². The capital, Natal, stands out as the most populous municipality, with over 750,000 inhabitants, followed by Mossoró, with around 264,000 inhabitants, and Parnamirim, with approximately 252,000 residents. The urbanization rate in RN is high, reaching 77.8%, while the average population density is 62.54 inhabitants per square kilometer, concentrated in coastal regions.

In the context of public health, RN is currently divided into eight health regions, named in an

ordinary manner. Each region has a municipality with greater representation, responsible for managing the health regulation process in the surrounding municipalities. In the first health region, the hub municipality is São José de Mipibu, followed in order by Mossoró, João Câmara, Caicó, Santa Cruz, Pau dos Ferros, Natal, and finally, representing the eighth, Assu [21, 22]. Figure 1 shows the distribution of health regions.

Furthermore, according to data from the National Register of Health Establishments (CNES) — https://cnes.datasus.gov.br/ — and the government data platform TabNET — http://tabnet.datasus.gov.br/ — Rio Grande do Norte has 6,173 health units. Of these, 1,326 are basic health units under municipal management, 10 are emergency care units (UPAs), and 21 are state hospitals. Of the hospitals in the state network, eight are concentrated in the seventh region, five in the second region, two in the first and fourth regions, and one in the third, fifth, sixth, and eighth regions. This configuration reflects the centralization of hospital services in the seventh (Natal) and second (Mossoró) regions, which may influence access to and the provision of specialized services to the population [21, 22].

Figure 1 - Distribution of health regions in Rio Grande do Norte
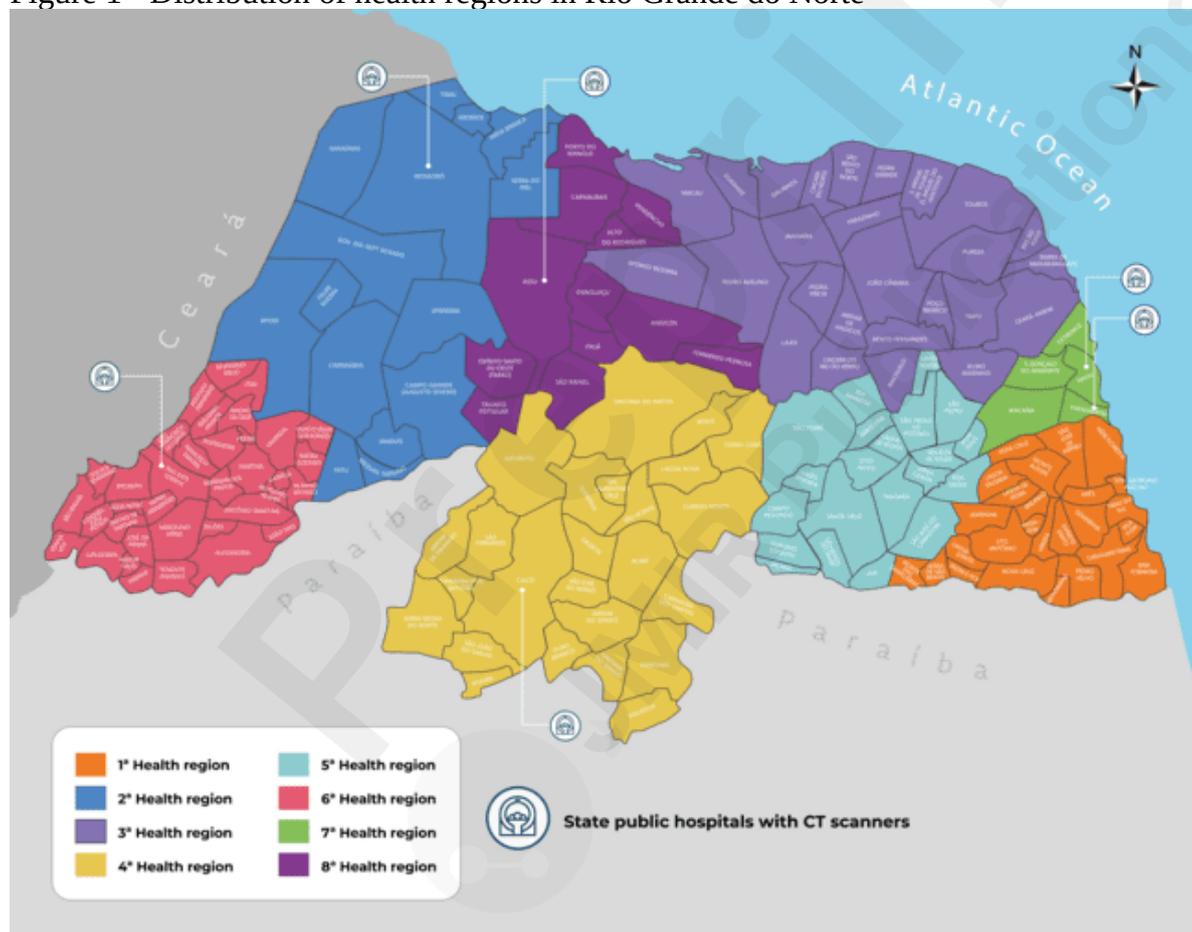
Methods

This study is characterized as applied research, with a quantitative and descriptive approach, focused on analyzing the use of computed tomography scanners in the state of Rio Grande do Norte. The investigation identifies the distribution of care between public sector health units and contracted private units, considering the potential absorption of demands currently met in both segments, with a focus on rationalization and identification of possible bottlenecks.

The data analyzed were extracted from the RegulaRN Ambulatorial platform, a state system

for regulating SUS procedures in RN. The database includes requests for CT scans registered between October 2023 and January 2025, with a total of 49,061 records. Each record initially contained 16 variables, which included information about the request, service, provider, and administrative characteristics of the procedure. It should be noted that the platform was structured to migrate data from the platform previously used to regulate state exams. However, this data was not considered in this study because it was not coherent with the study's objectives.

The methodological process was structured in four sequential stages: (1) Extraction, in which the original columns from the database were obtained, namely: request date, priority, status, patient name, gender, requesting unit, unit municipality, procedure name, subgroup, APAC (Outpatient Health Procedure Authorization) number, authorization date, regulating physician, provider unit, provider municipality, date of care, and date of completion. Following this, we carried out stage (2) Feature suitability, in which we preprocessed the temporal variables (dates), which initially had a unified date and time value. Therefore, we separated the date and time, and then created derived variables representing the time intervals between the following steps: (i) request and service; (ii) request and authorization; (iii) authorization and service; and (iv) service and closure. In addition, some characteristics were removed, namely columns that contained sensitive variables or that would not contribute significantly to this study, such as the patient's name, procedure subgroup, APAC number, and name of the regulating physician.

It was considered a Separation stage (3), given that the status of the requests could contain four different types of outcomes, namely: completed (75.60% of data), canceled (20.14% of data), removed (1.77% of data), and denied (2.49% of data). Thus, this analysis focused on records with completed and canceled status, as they presented greater volume and relevance to the study objectives. Records with removed and denied status were disregarded because they were not significant. Finally, an Exclusion stage (4) was included, in which data from outcome variables with removed and denied status were removed, as they did not contribute to the evaluation and objectives of this study. In this regard, the data used for this study consisted of 37,089 completed requests and 9,881 canceled requests. Figure 2 shows the sequence of this methodological process.

Figure 2 - Pipeline created for curating computed tomography exam data from RegulaRN Ambulatorial.
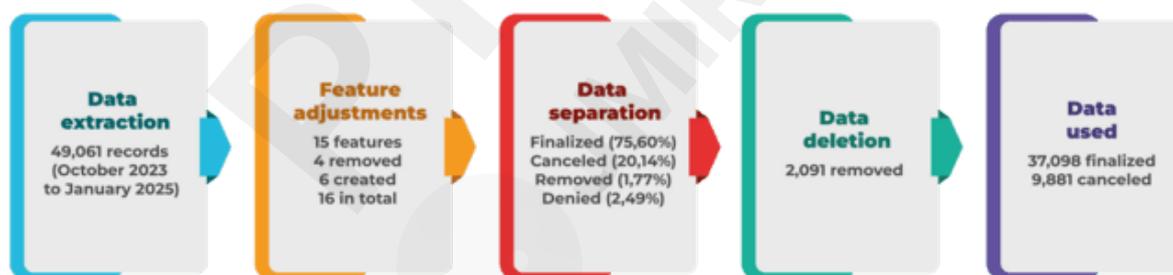
In order to enable the reproducibility of the methodological process, the anonymized data used to compose this research, within the specified period, can be accessed via the link on Zenodo [23] openly and free of charge.

Results

The results of this survey were organized to consider completed requests and canceled requests separately, in order to provide greater clarity and detail in the analyses presented.

Requests Completed

When considering the data profile of RegulaRN Ambulatorial, from October 2023 to January 2025, the 37,089 records of exam requests with the status "Completed" show a greater occurrence of data from oncology patients (in terms of priority), females (in terms of gender), requested mainly by two municipalities in the state of Rio Grande do Norte, Natal and Mossoró, for computed tomography of the chest, upper abdomen, and skull (in terms of procedure). Table 1 clearly shows the distribution of request data with the status "Completed."

Table 1 - Distribution of data from completed requests

Feature	Values (N = 37,089)
Categorical values	
Priority	Oncology: 24,769 (66.8%)
	Hospitalized: 2,221 (6.0%)
	Very high: 2,654 (7.2%)
	High: 3,831 (10.3%)
	Medium: 2,999 (8.1%)
	Low: 601 (1.6%)
	Lawsuit: 14 (< 0.1%)
Sex	Male: 14,386 (38.8%)
	Female: 22,703 (61.2%)
Requesting unit	Health unit 174: 8,336 (22.48%)
	Health unit 23: 2,966 (8.00%)
	Health unit 4: 1,622 (4.37%)
	Health unit 20: 1,585 (4.27%)
	Health unit 19: 1,535 (4.14%)
	Others: 21,045 (56.74%)
Requesting Municipality	Natal: 10,815 (29.16%)
	Mossoró: 3,691 (9.95%)
	Caicó: 1,133 (3.05%)
	Others: 21,450 (57.83%)

Procedure	Chest CT scan: 9,815 (26.46%)
	Upper abdominal CT scan: 9,688 (26.12%)
	Skull CT scan: 9,158 (24.69%)
	Others: 8,428 (22.72%)
Service provider unit	Health unit 4: 20,258 (54.62%)
	Health unit 3: 6,388 (17.22%)
	Health unit 12: 5,264 (14.19%)
	Health unit 11: 1,608 (4.34%)
	Health unit 2: 1,466 (3.95%)
	Others: 2,105 (5,68%)
Municipality provider	Natal: 27,527 (74.22%)
	Mossoró: 7,941 (21.41%)
	Caicó: 1,621(4.37%)

Numerical values	
Request to service	< 30 days: 25,256 (68.10%) > 30 days: 11,833 (31.90)
Request to authorization	< 30 days: 27,476 (74.08%) > 30 days: 9,613 (25.92%)
Authorization to service	< 30 days: 35,716 (96.30%) > 30 days: 1,373 (3.70%)
Service to closure	< 30 days: 31,512 (84.96%) > 30 days: 5,577 (15.04%)

Regarding time indicators, the average interval between the request and the service was 44.86 days, with a standard deviation of 88.43 days and a median of 20 days. The period between the request and authorization had an average of 38 days (standard deviation of 86.88 days) and a median of 12 days. The interval between authorization and treatment was, on average, 7 days (standard deviation of 15.51 days), with a median of 2 days. Finally, the average time between admission and discharge was 22.15 days, with a standard deviation of 30.91 days and a median of 14 days. These results indicate that the longest delays occur during the authorization and service periods, suggesting that demand exceeds the healthcare network's capacity to respond promptly.

Another relevant aspect concerns the distribution of agreements for the provision of examinations. The metropolitan areas of Natal, Mossoró, and Caicó are hubs of reference for other

municipalities. Because they have more robust infrastructure, these hub municipalities respond, through agreements, to requests from patients in other municipalities, whether or not they are located in their health region. Thus, Table 2 shows the number of completed requests from municipalities that performed some type of CT scan under agreement with the reference centers.

Table 2 - Distribution of completed requests to service provider units.

Municipality Provider	Requesting Municipality
Natal (27,527)	Natal: 10,810 (39.27%)
	São Gonçalo do Amarante: 1,102 (4.00%)
	Macaíba: 1,056 (3.84%)
	Parnamirim: 967 (3.51%)
	Ceará-Mirim: 664 (2.41%)
	Caicó: 614 (2.23%)
Mossoró (7,941)	Mossoró: 3,650 (45.96%)
	Açu: 570 (7.18%)
	Apodi: 367 (4.62%)
	Baraúna: 304 (3.83%)
	Caraúbas: 232 (2.92%)
	Areia Branca: 173 (2.18%)
Caicó (1,621)	Caicó: 519 (32.02%)
	Parelhas: 163 (10.06%)
	Currais Novos: 134 (8.27%)
	Apodi: 108 (6.66%)
	Jucurutu: 77 (4.75%)
	Serra Negra do Norte: 66 (4.07%)

In addition, it was possible to identify significant patient transfers between regions that have or do not have healthcare facilities with CT scanners. Table 3 presents data on the three provider units that receive the most requests and the municipalities and health regions from which the requests originate. It was possible to identify that Health Unit 4, belonging to the seventh health region of RN, expressly serves not only residents of its region but also those of other surrounding regions.

Table 3 - Distribution of the three service providers that receive the most requests and the municipalities/regions from which they are requested.

Service provider unit (health region)	Municipality	Municipal health region
Health unit 4 (7th)	Natal: 7,304	7th
	Parnamirim: 922	7th
	Macaíba: 875	7th
	São Gonçalo do Amarante: 817	7th
	Caicó: 600	4th
	Ceará-Mirim: 534	3rd
	Santa-Cruz: 437	5th
	Touros: 308	3rd
	São José de Mipibu: 286	1st
	Nova Cruz: 275	1st
Health unit 3 (2nd)	Mossoró: 3,301	2nd
	Apodi: 209	2nd
	Açu: 245	8th
	Baraúna: 222	2nd
	Caraúbas: 204	2nd
	Areia Branca: 121	2nd
	Patu: 113	2nd
	São Miguel: 89	6th
	Carnaubais: 82	8th
	Grossos: 82	2nd
Health unit 12 (7th)	Natal: 2,830	7th
	São Gonçalo do Amarante: 216	7th
	Ceará-mirim: 99	3rd
	Macau: 95	3rd
	Nova Cruz: 89	1st

Goianinha: 68	1st
Touros: 62	3rd
Canguaretama: 62	1st
Guamaré: 59	3rd
Pedro Avelino: 58	3rd

The procedures performed by healthcare providers are also relevant elements for analysis, especially those identified as the most frequently performed in the respective healthcare facilities. According to Table 1, health unit 4, health unit 3, and health unit 12 are among the institutions that receive the most patients. It is worth noting that the first two units mentioned are references for the care of oncology patients, representing approximately 66.8% of completed requests. Thus, in a preliminary assessment, it was already expected that these units would have a higher number of requests. In addition, as Table 1 also shows, there are three tests that are in high demand compared to the others, namely: CT scan of the upper abdomen, CT scan of the pelvis, lower abdomen, and chest. Therefore, it is expected that these procedures will also be widely demanded among these units (see Table 4 in Multimedia Appendix).

Still, when analyzing which units perform the most different types of procedures, health unit 4 was responsible for performing the most upper abdomen CT scans (5,362 in 2024), thoracic spine with or without contrast (81 in 2024), pelvis/lower abdomen (4,899 in 2024), face/sinuses/temporomandibular joints (361 in 2014), chest (5,790 in 2024), neck (833 in 2024), sella turcica (22 in 2024), and PET-CT (367 in 2024). Health unit 12 performed the highest number of CT scans of the upper limb (26 in 204) and lower limb (74 in 2024), lumbosacral spine with or without contrast (314 in 2024), and skull (1,183 in 2024). Finally, health unit 3 performed the most CT scans of the cervical spine with and without contrast (88 in 2024). A highlight of this analysis is that, in theory, any provider could perform any of the tomography exams, except for PET-CT, which requires a higher level of technology. However, the data shows a high distribution in terms of the number of inmates across different units. In addition, not all procedures refer to all units.

We consider analyzing the relationship between priority of care, provider unit, and municipality of the unit that requests the most (Table 5 in Multimedia Appendix). Our argument is that it is necessary to identify whether there is any correlation or direction between a specific service profile for a specific unit, and whether the number of requests for that unit is coming from a nearby municipality or not.

The study found that Health Units 3 and 4, although they are oncology centers, also address other priorities that could be allocated to other units, which contributes to a better distribution of demand. On the other hand, public hospitals such as Health Unit 5 (13 requests) and Health Unit 9 (87 requests) showed low service levels, with few records, most of them from outside municipalities, suggesting potential for greater use of this equipment and reduction in waiting times.

Another important element to highlight is the assessment of which CT scans are most frequently requested over time, as well as their cost, given that the most requested ones do not necessarily incur higher costs for the state government. This will enable the healthcare network to gain a general understanding of which specific tests are most in demand and, as the network

expands, what adjustments need to be made.

According to data obtained from the RegulaRN Ambulatorial database for 2023 (as of October), Computed Tomography of the Upper Abdomen, Computed Tomography of the Pelvis, and Upper Abdomen, and Computed Tomography of the Thorax cost approximately R$ 19,130.94, R$ 18,853.68, and R$ 19,779.45, respectively (see Table 6). For the year 2024, the most costly and in-demand procedures were also Computed Tomography of the Upper Abdomen, Computed Tomography of the Pelvis, and Upper Abdomen, and Computed Tomography of the Thorax, with the significant emergence of Positron Emission Tomography (PET-CT), costing approximately R$1,239,629.46, R$1,172,809.80, R$1,233,282.81, and R$840,780.78, respectively. In January 2025, the same exams remained the most in demand, with costs of R$84,287.04 (upper abdomen CT scan), R$77,910.06 (pelvis, and lower abdomen CT scan), R$85,801.89 (chest CT scan), and R$52,680.50 (PET-CT scan).

Table 6 - Representation of the total cost of procedures per year

Tomography procedure	Oct./2023	2024	Jan./2025
CT scan of Upper abdomen (R$ 138.63/ exam)	R$19,044	R$1,233.996	R$ 83,904
CT scan of Lower limb joints (R$86.75/ exam)	R$ 86.75	R$17,003	R$2,689.25
CT scan of upper limb joints (R$86.75/exam)	R$86.75	R$ 5,465.25	R$347
CT scan of the cervical spine with or without contrast (R$86.76/exam)	R$433.8	R$26,114.76	R$694.08
CT scan of the lumbosacral spine with or without contrast (R$101.10/exam)	R$1,415.4	R$70,871.1	R$2,628.6
CT scan of the thoracic spine with or without contrast (R$86.76/exam)	R$ 347.04	R$21,776.76	R$1,041.12
CT scan of the face/sinuses/temporomandibular joints (R$86.75/exam)	R$ 1,648.25	R$81,631.75	R$6,072.5
CT scan of the pelvis/lower abdomen (R$138.63/exam)	R$ 18,853.68	R$1,172,809.8	R$77,910.06
CT scan of appendicular segments - (arm, forearm, hand, thigh, leg, foot) (R$86.75/exam)	R$173.5	R$5,638.75	R$347
CT scan of the sella turcica	R$ 0.00	R$5,066.88	R$292.32

(R$97.44/exam)			
CT scan of the Thorax (R$136.41/exam)	R$19,779.45	R$ 1,233,282.81	R$ 85,801.89
CT scan of the Skull (R$97.44/exam)	R$6,138.72	R$368,323.2	R$16,662.24
CT scan of the Neck (R$86.75/exam)	R$ 1,735	R$ 96,032.25	R$ 7,200.25
Positron emission tomography (PET-CT) (R$2,107.22/exam)	R$8,428.88	R$840,780.78	R$ 52,680.5
Total	**R$ 78,170.54**	**R$ 5,178,793.09**	**R$ 338,270.56**

Regarding the costs associated with performing CT scans, considering that there are public and private healthcare facilities contracted and paid for with public funds, it is necessary to analyze the distribution of resources used in public healthcare throughout the period of this study. Finally, analyzing the budget distribution between public and private entities under contract, it was observed that public units (Health Units 5, 6, 8, and 9) accounted for less than 1% of the total investment in CT scans, with most resources directed to private and philanthropic healthcare networks (Units 1, 2, 3, 4, 7, 10, 11, 12, and 13).

Table 7 - Budgetary cost distribution by entity

	Oct./2023	**2024**	**Jan./2025**
Public	0	R$ 45,356.42 (0.88%)	R$ 2,731.74 (0.81%)
Private	R$ 78,170.54 (100%)	R$5,133,436.67(99.12%)	R$335,538.82 (99.19%)

Canceled Requests

A total of 9,881 records of canceled requests were analyzed, the evaluation of which is essential for identifying patterns and possible gaps in the regulatory process. Cancellation may occur at any time, from the request until after service, and is carried out by the requesting unit. Table 8 (in Multimedia Appendix) details the distribution of cancellations and indicates that the highest concentration occurs in the initial stages of the request, as well as after the service has been provided by the provider unit. This pattern suggests inefficiencies in the early identification of requests that will be canceled, resulting in unnecessary expenditure of time and human resources in analyzing requests that could have been discarded beforehand.

Following the results, it was also possible to identify that among the canceled requests, there is a greater significance in requests prioritizing oncology patients and female patients, which was expected given the greater significance throughout the dataset. As for the requesting unit and

procedures indicators, there are the following variations: among the canceled requests, the highest number of requests comes from Health Unit 102, belonging to the municipality of Macaíba, which is located in the metropolitan region of Natal. Although this municipality does not appear significantly in the number of completed requests, it has a higher number of requests canceled in the initial phase. This may represent some difficulty that this municipality faces or has faced in making new requests.

As for the procedure, Computed Tomography of the Upper Abdomen, which is one of the most requested exams, is also among the most canceled. For requests that were only authorized, it should be noted that the requesting units are hospital units, with Health Unit 32 having the highest recurrence of cancellations after authorization. The most canceled procedure at this stage is chest computed tomography. As for requests that were actually fulfilled, Health Unit 23, belonging to the municipality of Natal, has the highest number of cancellations. The most canceled procedure at this stage is chest computed tomography.

Discussion

The optimization of health services as a constitutional obligation

The 1988 Constitution of the Federative Republic of Brazil, by establishing the National Health System (SUS) and adopting a model of universal and free access inspired by the British system (Beveridge model), recognized health as a right for all and a duty of the State. Under Article 198 of the Constitution, public health actions and services must form a regionalized and hierarchical network, with decentralized organization and participation by federal entities — the Union, states, Federal District, and municipalities —, each of which is responsible for adopting legal, economic, and practical measures aimed at realizing this fundamental right [24].

This constitutional effort to structure the SUS as a federation highlights the joint responsibility of the entities involved in ensuring the provision of quality health services to the population. To this end, public managers are required to perform their duties as efficiently as possible in order to optimize the relationship between revenue and expenditure. This guideline is reinforced by the principle of efficiency, enshrined in the heading of Article 37 of the Federal Constitution, which should guide all administrative activity.

The existence of essential health equipment and services in a state of idleness is incompatible with the constitutional order and governing legislation, especially given the growing demands of the Brazilian population. Incompatibility becomes even more evident in the case under review when it is noted that, although there is ordinary and continuous demand for CT scans, it has been met by the private sector as if it were an exceptional service, while a public network capable of offering such procedures remains idle.

Law No. 8,080/1990, which regulates the SUS, establishes in Article 7, items II, IV, and XI, that health actions and services must be organized based on the principles of comprehensive care, preservation of personal autonomy, and rational use of resources, and that it is the duty of managers to promote the full use of installed capacity, avoid waste, and ensure the efficient use of available resources [25].

The regulation of public health financing, in turn, was consolidated with Complementary Law No. 141, of January 13, 2012, which regulates paragraph 3 of article 198 of the Constitution. The law defined the criteria for apportioning federal, state, and municipal resources, defined what is

meant by expenditures on public health actions and services (Article 3), and reaffirmed the minimum revenue requirements set forth in Article 77 of the Brazilian ADCT. In addition, Complementary Law 141/2012 reinforced the mandatory use of health funds and the need for transparent mechanisms for controlling and monitoring public spending (Articles 12, 14, and 16) [26].

Constitutional Amendment No. 86/2015 (known as the "Mandatory Budget Amendment") reinforced this regulatory framework by establishing a minimum level of federal health spending in the Constitution, making it mandatory to allocate a portion of individual parliamentary amendments to the health sector. The amendment also linked funds from oil royalties to public health actions and services, with the aim of increasing funding and ensuring its stability. In turn, Constitutional Amendment 95 of 2016, which was only reversed in 2023, established a freeze on public spending for 20 years, imposing an environment of great fiscal austerity, in which health was heavily impacted by the loss of resources [27].

Given the regulatory landscape of fiscal austerity and the recognized budgetary constraints that limit government action, efficiency in public health management is a constitutional duty, directly linked to the state's obligation to ensure the fundamental right to health in a universal, equitable, and comprehensive manner. The Brazilian National Health System is facing growing demands and limited resources, so public managers need to make the best use of available resources, getting the most out of public policies and avoiding waste.

In this scenario, the adoption of management practices aimed at rationalizing expenses and enhancing installed capacity becomes imperative. In this case, it was found that, even in the face of continuous and routine demand for CT scans, the State chose to pay for such services from the private network, despite the existence of idle public equipment that was suitable and available to meet the same demand.

Such conduct constitutes flagrant administrative inefficiency and disregard for the constitutional principles of economy, legality, and good governance. Discussing health economics, therefore, is not just a management issue, but a legal and ethical requirement, essential for addressing social and regional inequalities. Article 6 of the Federal Constitution establishes health as a fundamental social right, while Articles 196 et seq. impose on the State the duty to guarantee it based on the principles of universality, equity, and comprehensiveness [2].

Thus, the constitutional order establishes the imperative that public health management act efficiently, especially in the use of highly complex technologies such as computed tomography, promoting the best use of the existing public infrastructure before resorting, unjustifiably, to the private sector.

Therefore, the search for the optimal path in economic terms, especially with regard to the allocation of highly complex equipment such as CT scanners, is directly linked to the legal duty to promote strategic planning, the evaluation of health technologies, and the maximization of the installed capacity of the public system. The existence of tomography equipment lying idle in public health facilities, when there is demand for the service, not only represents a waste of resources, but also constitutes a flagrant affront to the constitutional principles of efficiency, economy, and reasonableness in public administration.

In the specific case of Rio Grande do Norte, the severity of the lack of availability of CT scan services is even more pronounced. As demonstrated in this study, the demand for the exam is concrete, growing, and well documented, but it has been met mainly by private providers contracted by the SUS, even in regions where there are underutilized or inoperative public CT scanners. This finding reveals not only an operational failure, but also a serious affront to the constitutional principles of economy and efficiency, which impose on the Public Administration the

duty to optimize resource management — that is, to use the least amount of public resources possible to achieve the highest degree of effectiveness in the service provided.

The allocation of public funds for the contracting of private tomography services, to the detriment of the use of existing public infrastructure, demonstrates a failure to comply with the duty of management optimization, constituting conduct that is uneconomical, inefficient, and inconsistent with the provisions of Article 37 of the Federal Constitution. The use of public funds to pay for services that could be performed by equipment that is already available — but underutilized — directly contradicts the logic of good administration and represents unjustifiable waste in a scenario of chronic budgetary scarcity.

The inefficiency of healthcare in Rio Grande do Norte: discussion of the data obtained

Considering the scarcity of financial resources within the SUS, efficiency in public management is an essential element for the sustainability of the system. Historically, the public health sector in Brazil has had high healthcare costs, which can be attributed to multiple factors, such as increased demand, the incorporation of advanced technologies, a shortage of qualified professionals, waste in the healthcare chain, and institutional management failures. In the case of highly complex exams, such as CT scans, for example, which involve higher public funding costs, monetary management must be more effective [28, 29].

The findings of this study reveal that most patients undergoing CT scans through the SUS in the state of RN are primarily oncology patients, with a significant concentration of care in three contracted private healthcare facilities. In view of this, a relevant discussion concerns the possibility of distributing these services to other hospital, mainly in state hospitals, which, according to the data, have a low number of patients. Or promote a greater number of consultations for non-oncology patients among state hospitals.

It should be noted that, of the twenty-one state hospitals, eight of them have CT scan equipment to meet demand, namely: Giselda Trigueiro Hospital, Dr. Tarcísio Maia Regional Hospital, Dr. Cleodon Carlos de Andrade Hospital, Nelson Inácio dos Santos Regional Hospital, Telecila Freitas Fontes State Hospital, Coronel Pedro Germano Central Hospital, Deoclécio Marques de Lucena Regional Hospital, and Monsenhor Walfredo Gurgel Hospital; However, only three of these hospitals performed some type of CT scan to meet the state's outpatient care demand, and even then, they performed a relatively small number of scans when compared to other units.

According to studies available in academic literature, the minimum capacity of a CT scanner is around 40 exams per day [30, 31] Therefore, the hospitals mentioned above are far below their maximum operational capacity. From this perspective, it is suggestive that competent institutions promote a protocol for redistributing the allocation of demands of at least 20% of what is suggested in the literature. Not only to reduce public spending, but also to reduce average waiting times.

The need to increase the number of appointments at state hospitals in the network is essential to promote greater patient care capacity and minimize waiting times [32]. Given that there is a continuous flow of oncology patients, those with lower priority in the queue wait considerably longer to be seen, to the point that they choose to have the exam done at a private facility at their own expense.

From this perspective, the results indicate two important points. The first concerns the fact that, although CT scans are considered a high-cost procedure, there are few records of legal proceedings. This phenomenon can be explained by the private sector's ability to offer payment alternatives that facilitate access for patients from the public system. The second aspect concerns the impact of long wait times in public services: patients with a history of public health care services

choose to undergo examinations in the private healthcare network, bearing the costs to ensure faster diagnosis.

Furthermore, from a macro-regional perspective, some health regions, such as the first, third, and fifth, do not have referral hospitals with CT scan equipment, meaning they do not have the capacity to meet local demand. Therefore, it is necessary for residents to travel a considerable distance so that the nearest providers can serve them. Thus, expanding the capacity of local hospitals to perform these tests could significantly contribute to reducing the need for travel and increasing access.

It was also observed that, among the thirteen hospitals that perform CT scans, there is a significant concentration of procedures in a few contracted private units, while the idle capacity of the public network remains underutilized. This concentration not only leads to increased public costs, but also reduces the autonomy of the SUS in providing essential services. As pointed out by Botega, Andrade, and Guedes [33], Brazilian public hospitals often operate below capacity, which reinforces the need for a strategic redistribution of demand to maximize the use of public resources, reduce costs, and foster competition among providers, thereby enhancing the quality and efficiency of care.

As for records of canceled requests, this work presents a considerable volume of requests. In addition, subdividing cancellation periods is also important for identifying where the main bottlenecks lie, given that a request that is made and then canceled for trivial reasons as the days go by systematically contributes to further delays in service. Therefore, institutional intervention is necessary to resolve the main issues presented in the results of this study [34].

Regarding social impact, optimizing the use of CT scanners in public facilities has the potential to expand access to diagnostic exams, reduce waiting times, and minimize waiting times. This effect would be especially relevant for patients classified as lower priorities, who currently experience low service rates in the system. Furthermore, such improvements would not be limited to regions with greater service availability, extending benefits to smaller municipalities and areas lacking dedicated equipment, thus contributing to the promotion of equity in healthcare access.

The results for Rio Grande do Norte reveal typical challenges faced by public health systems in developing countries, where the concentration of high-cost technologies in a few urban hubs creates territorial inequalities and pressures referral hospitals, resulting in longer waiting times and potential underdiagnosis of diseases. This situation reinforces the importance of strategic planning for the allocation of new equipment, guided by epidemiological needs, population density, and the installed capacity of health units.

Finally, the results highlight the need to review contracts between the state, municipalities, and service providers, given that some establishments may be serving beyond the necessary demand, while others face difficulties in ensuring adequate access for the population. This review is essential to ensure the equity, efficiency, and sustainability of the public health system in RN.

Conclusions

This study highlights significant distortions in the allocation and utilization of CT scanners in Rio Grande do Norte's public health system, characterized by the concentration of care in a limited number of contracted private units, despite the existence of underutilized equipment in state public hospitals. These findings suggest the possibility of expanding the installed capacity of the Unified Health System (SUS), with positive impacts on reducing wait times and operating costs. Furthermore, it is noteworthy that the future use of analytical tools based on artificial intelligence could provide important support for prioritizing exams and redistributing the healthcare burden more equitably and efficiently.

The evidence produced in this study can support managers in assessing the absorption

capacity of currently outsourced demand, while also reinforcing the importance of more strategic regulation that is sensitive to regional disparities, ensuring equal access to CT scans throughout the state. Regarding limitations, we highlight the incompleteness of data for the entire period between 2023 and 2025, as well as the possibility of inconsistencies in information migrated from previous platforms. The availability of complete historical data would allow for a more comprehensive and contextualized analysis of the performance of service providers. Therefore, to mitigate the impacts arising from the transition between systems in the public sector, we recommend the adoption of periodic audits and data quality frameworks, as recommended by DATASUS (Brazil, 2023), to preserve the greatest possible integrity of the information.

For future research, we recommend conducting a longitudinal analysis to assess the effects of restructuring regional contracts, as well as investigating the impact of judicialization resulting from the unavailability of tests. Furthermore, the possibility of replicating the methodology adopted in other high-cost procedures expands the potential contribution to strengthening the rational management of the SUS, promoting greater efficiency and equity in the use of available resources.

Author contribuitions

TOB: Conceptualization, Data curation, Formal analysis, Methodology, Results, Software, Writing—original draft, Writing—review & editing. EBOJ: Conceptualization, Data curation, Methodology, Results, Writing—original draft, Writing—review & editing. IJSF: Conceptualization, Data curation, Methodology, Results, Writing—original draft, Writing—review & editing. PHC: Conceptualization, Data curation, Methodology, Software, Writing—review & editing. JCLP: Conceptualization, Data curation, Methodology, Results, Writing—review & editing. LMS: Data curation, Methodology, Writing—review & editing. JMMC: Data curation, Methodology, Writing—review & editing. NVRV: Data curation, Methodology, Writing—original draft, Writing—review & editing. ESA: Conceptualization, Methodology, Results, Writing—review & editing. TGFMSL: Conceptualization, Methodology, Results, Writing—review & editing. CCB: Methodology, Results, Writing—review & editing. RSS: Methodology, Results, Writing—review & editing.
LSCL: Methodology, Results, Writing—review & editing. ASP: Methodology, Results, Writing—review & editing. FRA: Data curation, Methodology, Results, Writing—original draft, Writing—review & editing. GMM: Conceptualization, Data curation, Methodology, Results, Writing—review & editing. CMV: Data curation, Methodology, Results, Writing—review & editing. KC: Conceptualization, Methodology, Supervision, Writing—review & editing. RV: Conceptualization, Methodology, Project administration, Supervision, Writing—original draft, Writing—review & editing.

Acknowledgements

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Abbreviations

APAC: Outpatient Health Procedure Authorization
CT: Computer Tomography
OECD: Organisation for Economic Co-operation and Development
RN: Rio Grande do Norte
SUS: Brazilian National Health System

References

1. Del Nero CR. O que é economia da saúde. 1995.

2. Brasil. Constituição da república federativa do Brasil de 1988. Brasília, DF: Presidente da república;[2025]. Available at: http://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm.

3. Barbosa DVS, Barbosa NB, Najberg E. Health regulation: challenges to the unified health system governance. Cadernos Saúde Coletiva;2016(24):49-54. doi:10.1590/1414-462X201600010106.

4. Silva JPT. Analysis of the efficiency of regional hospitals in a northeastern brazilian state. Saúde em Debate;2019(43-120):84-97. doi:10.1590/0103-1104201912006.

5. Silva SN et al. Implementation of health technologies in brazil: analysis of federal guidelines for the public health system. Ciência & Saúde Coletiva;2024(29):e00322023. doi:10.1590/1413-81232024291.00322023.

6. Owen L et al. The cost-effectiveness of public health interventions. J Public Health;2012(34-1):37-45. doi:10.1093/pubmed/fdr075.

7. OECD. OECD reviews of health systems: Brazil 2021. OECD Rev Health Syst;2021:OECD Publishing; Paris. doi:10.1787/146d0dea-en.

8. Cerda AA et al. Comparison of the healthcare system of chile and brazil: strengths, inefficiencies, and expenditures. Cost Effectiveness Resource Alloc;2022(20-1):71. doi:10.1186/s12962-022-00405-9.

9. Brasil. Lei nº 15.121, de 10 de abril de 2025. Estima a receita e fixa a despesa da união para o exercício financeiro de 2025. Diário Oficial da União: edição extra, Brasília, DF, 10 abr. 2025. Available at: https://www.planalto.gov.br/ccivil_03/_ato2023-2026/2025/lei/L15121.htm
. Accessed on: 05 jun. 2025.

10. Iyamu I et al. Defining digital public health and the role of digitization, digitalization, and digital transformation: scoping review. JMIR Public Health Surveill;2021(7-11):e30399. doi:10.2196/30399.

11. Richardson S et al. A framework for digital health equity. NPJ Digital Medicine;2022(5-1):119.

12. Romans L. Computed tomography for technologists: exam review. Lippincott Williams & Wilkins;2018.

13. Santos DLD. Distribuição da tomografia computadorizada e do grau de utilização do tomógrafo computadorizado no sus. Dissertação de mestrado (UFBA);2013.

14. Santos DL dos A et al. Ct scanners in the brazilian unified national health system: installed capacity and utilization. Cadernos Saúde Pública;2014(30):1293-1304. doi:10.1590/0102-311X00140713.

15. Dovales AC et al. Patterns and trends of computed tomography usage in outpatients of the brazilian public healthcare system, 2001–2011. Journal of Radiological Protection;2016(36-3):547. doi:10.1088/0952-4746/36/3/547.

16. Viacava F et al. SUS: supply, access to and use of health services over the last 30 years. Ciência & Saúde Coletiva;2018(23):1751-1762. doi:10.1590/1413-81232018236.06022018.

17. Valentim RAM et al. The relevance a technology ecosystem in the brazilian national health service's covid-19 response: the case of rio grande do norte, brazil. Ciência & Saúde Coletiva;2021(26):2035-2052. doi:10.1590/1413-81232021266.44122020.

18. Barreto TO et al. Artificial intelligence applied to analyzes during the pandemic: covid-19 beds occupancy in the state of rio grande do norte, brazil. Frontiers in Artificial Intelligence;2023(6):1290022. doi:10.3389/frai.2023.1290022

19. Barreto TO et al. Artificial intelligence applied to bed regulation in Rio Grande do Norte: data analysis and application of machine learning on the "RegulaRN Leitos Gerais" platform. PloS One;2024(19):e0315379. doi:10.1371/journal.pone.0315379

20. IBGE. Censo 2022. 2022. Available at: https://censo2022.ibge.gov.br/panorama/
. Accessed on: 05 jun. 2025.

21. Bezerra MV. Análise da utilização da escala quick sequential organ failure assessment para tomada de decisão na regulação de leitos de uti. 2023.

22. Barreto TO. Inteligência artificial aplicada ao ecossistema de regulação do estado rio grande do norte (RegulaRN): análises baseadas em machine learning em leitos covid-19 e leitos gerais. 2024.

23. Zenodo. RegulaRN Outpatient Computed Tomography Data. Available at: https://zenodo.org/records/15830664.

24. Santos RCC dos. Financiamento da saúde pública no brasil. Belo Horizonte: Fórum;2016.

25. Brasil. Lei 8.080 de 1999. Available at: https://www.planalto.gov.br/ccivil_03/leis/l8080.htm

26. Brasil. Lei complementar 141 de 2012. Available at: https://www.planalto.gov.br/ccivil_03/leis/lcp/lcp141.htm

27. Benevides RP de Sá, Funcia F. Desafios para melhorar a qualidade dos gastos do sus. 2023.

28. Nunes Júnior NB, Pacheco MAB. The cost-effectiveness of imaging examinations as a parameter of efficiency in a health service in the diagnosis of community acquired pneumonia. Saúde Coletiva (Barueri);2023(13-86):12537-12560. doi:10.36489/saudecoletiva.2023v13i86p12537-12560.

29. Ocké-Reis CO et al. SUS: avaliação da eficiência do gasto público em saúde. 2023.

30. Dang W et al. Does distance matter? Effect of having a dedicated ct scanner in the emergency department on completion of ct imaging and final patient disposition times. J Am Coll Radiol;2015(12-3):277-283. doi:10.1016/j.jacr.2014.11.003.

31. Carvalho EM de M et al. Planning and administration of environmental security and care in health services. Revista de Pesquisa: Cuidado é Fundamental;2018(10-1):224-232. doi:10.9789/2175-5361.2018.v10i1.224-232.

32. Bittencourt O, Verter V, Yalovsky M. Hospital capacity management based on the queueing theory. Int J Productivity Performance Manag;2018(67-2):224-238. doi:10.1108/IJPPM-12-2015-0193.

33. Botega LA de A, Andrade MV, Guedes GR. Brazilian hospitals' performance: an assessment of the unified health system (sus). Health Care Manag Sci;2020(23):443-452. doi:10.1007/s10729-020-09505-5.

34. Chandra D, Tiwari A. A systematic survey on different modeling methods to manage waiting time in ambulatory patient services. International Journal;2019(7-2):84-90

35. Brasil. Trindade GMN. Datasus: metodologia de administração de dados. 2023. Available at: https://datasus.saude.gov.br/wp-content/uploads/2023/12/Metodologia-de-Administracao-de-Dados-MAD.pdf . Accessed on: 28 jun. 2025

Supplementary Files