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RADIOTHERAPY SERVICES IN BRAZIL: AN OVERVIEW OF DEMAND AND INSTALLED CAPACITY[1]

SERVIÇOS DE RADIOTERAPIA NO BRASIL: ANÁLISE DA DEMANDA E DA CAPACIDADE INSTALADA

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ABSTRACT

This study mapped the availability of radiotherapy services in Brazil. It compares data from three official agencies to correlate the ideal percentages of equipment in relation to the number of inhabitants in the country, according to the World Health Organization (WHO). A statistical analysis was performed to assess quantity of existing radiotherapy by different regions of Brazil. It was found that the three consulted official agencies presented divergent data. Moreover, while all Brazilian regions and states have a low number of radiotherapy services, the Northeast region stands at the bottom. However, the Brazilian Radiotherapy Expansion Plan aims to improve this situation.

Keywords: Neoplasms. Tertiary treatment. Unified Health System. Brazilian public health.

RESUMO

Este trabalho realizou um mapeamento da disponibilidade de serviços de radioterapia no Brasil, comparando dados de três órgãos oficiais para correlacionar as porcentagens ideais de equipamentos em relação à quantidade de habitantes do país, segundo a Organização Mundial de Saúde. Foi feita uma análise estatística avaliando a associabilidade entre o quantitativo de equipamentos existentes e as

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diferentes regiões do Brasil. Constatou-se que, mesmo sendo fontes oficiais, os diferentes canais de comunicação apresentam dados divergentes e que todas as regiões e estados brasileiros apresentam um número inferior de serviços de radioterapia, sendo o pior cenário na região Nordeste. Apesar disso, o Plano de Expansão da Radioterapia, do Governo Federal, visa a melhoria desse cenário.

Palavras-chave: Neoplasias. Tratamento terciário. Sistema Único de Saúde. Saúde pública brasileira.

INTRODUCTION

Radiotherapy uses ionizing radiation to combat neoplasms. It aims to reach malignant cells and prevent their multiplication by mitosis and/or determining cell death (Brazilian National Cancer Institute José Alencar Gomes da Silva [INCA], 2022). This technique is used in approximately 70% of all cases of diagnosed malignant tumors (Brazilian Society Of Radiotherapy [SBRT], 2023), including those with the highest incidence in Brazil. Among these, breast cancer ranks first, followed by lung, colon and rectal, and prostate cancer. The projection for Brazil is 704 new neoplastic cases in the 2023-2025 triennium (INCA, 2023). By 2030, the country will need to acquire 329 radiotherapy units (RUs) to meet the needs of the population, which is complicated by the extra burdens of acquiring and maintaining the infrastructure required to perform radiotherapy (SBRT, 2020).

In addition, socioeconomic differences promote inequality among Brazilian regions, which is, in turn, reflected in disproportionate health services, notwithstanding services provided by the Unified Health System (Sistema Único de Saúde - SUS) (Andrade et al, 2013).

Since we expect the need for cancer treatment to grow, an assessment of current radiotherapy services available in Brazil will give healthcare providers, decision-makers and managers of public resources the data they need to mount an effective fight against cancer in the coming years. This provides the rationale for the present work which aims to map radiotherapy services currently available in Brazil to determine, quantitatively, if such services can meet the treatment needs of the population in each region of the country in accordance with the goals proposed by WHO (Correa, 2019).

A bibliographic and documentary research was carried out utilizing websites of the Ministry of Health (MS), National Nuclear Energy Commission (CNEN), Brazilian Radiotherapy Society (SBRT), National Cancer Institute (INCA) and Brazilian Institute of Geography and Statistics (IBGE).[2]

We used Microsoft Excel software to tabulate, compare and graph the information collected, as well as two-dimensional analysis, through statistical measures associated with quantitative variables arranged in a joint distribution. This involved examining the relationship between two variables, often using concepts like joint probability distributions, correlation, and conditional probabilities.

RESULTS AND DISCUSSION

The number of radiotherapy services in Brazil, as determined from the various official registration portals noted above, differs. More specifically, according to the Brazilian Society of Radiotherapy (SBRT, 2023), we have 288 radiotherapy facilities, while the total registration of services regulated by the National Nuclear Energy Commission in 2026 is 319 facilities [3] , and data from the Ministry of Health in 2022 show a total of 171 RUs.

In this work, the facilities that offer radiotherapy treatment are designated as Radiotherapy Units (RU), and they were separated and tabulated by regions and states within regions of Brazil, as well as by data source. These data are shown in Table 1.

Table 1: Quantity of RUs by states in the regions and data source.

Region	States\Data source	SBRT	CNEN	MS
North	Acre (AC)	1	0	1
	Amapá (AP)	0	1	0
	Amazonas (AM)	4	4	1
	Pará (PA)	6	5	2
	Rondônia (RO)	3	2	3
	Roraima (RR)	0	0	0
	Tocantins (TO)	2	3	2
	RUs in the North region	**16**	**15**	**9**
Northeast	Alagoas (AL)	4	4	3

[2]Ministry of Health: https://www.gov.br/saude/pt-br
National Council of Nuclear Energy: https://www.gov.br/cnen/pt-br
Brazilian Society of Radiotherapy: https://sbradioterapia.com.br/
National Cancer Institute: https://www.gov.br/inca/pt-br
Brazilian Institute of Geography and Statistics: https://www.ibge.gov.br/

[3]Since data is constantly updated on the CNEN platform, this work considers data available in March, 2026.

	Bahia (BA)	11	13	9
	Ceará (CE)	5	5	3
	Maranhão (MA)	3	4	2
	Paraíba (PB)	4	3	2
	Pernambuco (PE)	8	8	5
	Piauí (PI)	2	4	2
	Rio Grande do Norte (RN)	2	1	2
	Sergipe (SE)	2	4	2
	RUs in the Northeast region	**41**	**46**	**30**
Central-West	Distrito Federal	9	8	2
	Goiás	7	8	3
	Mato Grosso	5	5	2
	Mato Grosso do Sul	6	6	3
	RUs in the Central-West region	**27**	**27**	**10**
Southeast	Espírito Santo	3	6	2
	Minas Gerais	32	33	26
	Rio de Janeiro	31	38	14
	São Paulo	84	96	40
	RUs in the Southeast region	**150**	**173**	**82**
South	Paraná	20	19	12
	Rio Grande do Sul	22	22	18
	Santa Catarina	14	17	10
	RUs in the South region	**56**	**58**	**40**
	Grand total	**290**	**319**	**171**

Source: Author's own elaboration

In the North region, records were obtained ranging from a total of 9 to 16 facilities offering radiotherapy services. The highest number was recorded by SBRT and the lowest by the Ministry of Health. Based on these numbers, we calculated the variability index (Δ), or dispersion, of the number of facilities per region, which is the total range of variation of the data calculated, as shown in Eq. 1 (Bussab; Morettin, 2004) (Montgomery; Runger, 2021):

$$\Delta = \boldsymbol{value_{max} - value_{min}} \textbf{ (Eq.1)}$$

Therefore, in the North region, the variability of distribution is 7 RUs, which represents about 43.8%, relating to maximum values, indicating a degree of variability that deserves attention. Such installations are concentrated mainly in state capitals, such as Rio Branco (AC), Manaus (AM), Belém (PA), Porto Velho (RO) and Palmas (TO), as well as other hub cities, such as Santarém (PA), Cacoal (RO) and Araguaína (TO).

It is worth noting that no records show facilities offering radiotherapy treatment in the states of Amapá and Roraima and that region Northeast has the lowest number of RUs compared to the rest of the country.

For the Northeast region, records range from 30 to 46 available facilities, but these RUs are also concentrated in the capitals and reference cities of the respective states, such as Maceió (AL), Arapiraca (AL), Salvador (BA), Barbalha (CE), Fortaleza (CE), Sobral (CE), São Luís (MA), Imperatriz (MA), Campina Grande (PB), João Pessoa (PB), Recife (PE), Teresina (PI), Mossoró (RN), Natal (RN) and Aracajú (SE). The variability index Δ(Eq. 1) for this region is 16 units, a variability of approximately 34.8% fewer registered facilities. The most discrepancy was found in the number of RUs registered by MS, which was lower.

The Central-West region has no variability between the SBRT and CNEN records. Meanwhile, records from the Ministry of Health data shows 10 RUs in total, different from the other two sources combined. The total range of variation of the data Δ(Eq. 1) is 17 units, indicating a degree of variability of 63.0%, which, again, deserves attention. Following the pattern of the North and Northeast regions, RUs in the Central-West region are concentrated in the capitals and most prominent cities in each of the states, e.g., Brasília (DF), Goiânia (GO), Anápolis (GO), Cuiabá (MT), Dourados (MS) and Campo Grande (MS).

The Southeast region stands out as having the highest number of RUs registered in all sources and the highest variability of data, ranging from 82 to 173 RUs. The highest number was reported by CNEN and the lowest by the Ministry of Health. The variability index Δ(Eq. 1) for this region is 91 units, or a variability of 52.6 %, the largest variability among all the regions of Brazil.

Espírito Santo is the state with the least number of facilities in the region, and the pattern of concentration of RUs is repeated since the capital city of Vitória has the highest number of units. The other states show greater variability of RUs, especially in the interior and regions farther away from the capital, e.g., cities such as Uberlândia (MG), Uberaba (MG), Juiz de Fora (MG), Montes Claros (MG), Niterói (RJ), Campos de Goytacazes (RJ), Ourinhos (SP), São José dos Campos (SP), Mogi das Cruzes (SP), Bauru (SP), Campinas (SP), and São José do Rio Preto (SP). As expected, a higher number of RUs can be found for São Paulo (SP), Belo Horizonte (MG) and Rio de Janeiro (RJ), following the same pattern of concentration.

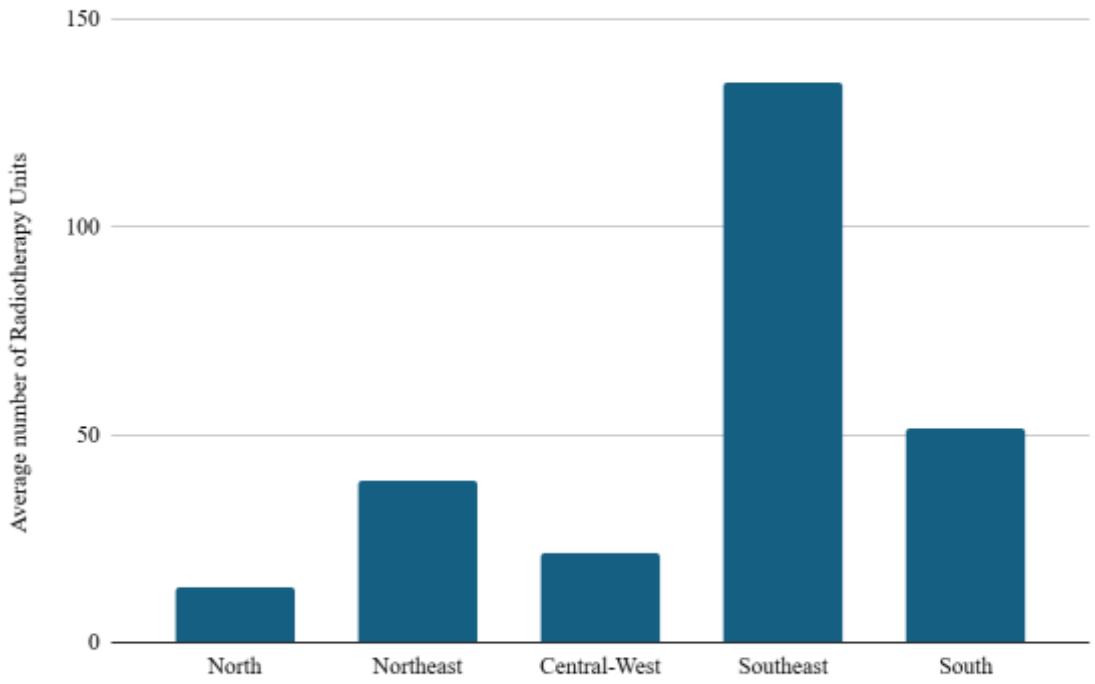
Finally, records from the South region range from 40 to 58 RUs. SBRT registered the highest number. The lowest number of RUs was recorded by MS. The

variability index Δ (Eq. 1) for this region is 18 units, representing 31.0% of the variability in the total number of RUs in Brazil.

In these states, we observed a relative distribution of units since the highest number of facilities are concentrated in the capitals, e.g., Florianópolis (SC), Porto Alegre (RS) and Curitiba (PA), but RUs are also found in cities with greater regional coverage, such as Balneário Camboriú (SC), Blumenau (SC), Joinville (SC), Pelotas (RS), Maringá (PR) and Londrina (PR).

In Graph 1, we can see the average number of RUs in all Brazilian regions. Average values were used to better visualize the regions with the highest and lowest number of RUs. We can see that the Southeast region has the highest number of cancer treatment facilities. The state of Roraima in the North region, has no RUs.

Graph 1: Average number of Radiotherapy Units by regions in Brazil.



Source: Author's own elaboration

However, to carry out a true analysis of the Brazilian panorama, it is necessary to consider populations of the respective states, thus making it possible to confirm the density of RUs according to the local population.

According to the Brazilian Institute of Geography and Statistics (IBGE) data from 2024, the main governmental institute responsible for providing data and information in Brazil, the Brazilian population currently totals 212,583,750 inhabitants out of which 18,669,345 people live in the North region, 57,112,096 live in the Northeast region, 17,071,595 live in the Central-West region, 88,617,693 live in the Southeast region and 31,113,021 live in the South region. The total number of

neoplastic cases registered by the National Cancer Institute (INCA, 2023), until 2022 is 25,460 cases for the North region, 152,930 cases for the Northeast region, 51,340 cases for the Central-West region, 345,230 cases for the Southeast region and 129,120 cases for the South region, as shown in Table 2.

According to Ordinance No. 741 of the Health Care Secretariat of the Ministry of Health of Brazil of 2005, for every 1,000 cancer patients, it is estimated that 600 will require radiotherapy treatment. Therefore, the number of cases treatable with radiotherapy by region was estimated to be 15,276 cases for the North region, 91,758 for the Northeast region, 30,804 for the Central-West region, 207,138 for the Southeast region and 77,472 cases for the South region, as shown in Table 2.

Table 2: Population size by region of Brazil with respective cancer cases registered by INCA and estimated cases needing radiotherapy treatment.

Region of Brazil	Population (IBGE)	Cancer cases registered (INCA)	Estimated cases needing radiotherapy treatment
North	18.669.345	25.460	15.276
Northeast	57.112.096	152.930	91.758
Central-West	17.071.595	51.340	30.804
Southeast	88.617.693	345.230	207.138
South	31.113.021	129.120	77.472
TOTAL	212.583.750	704.080	422.448

Source: Author's own elaboration

This type of study calls for an assessment of the density of radiotherapy equipment in relation to the Brazilian population. Such analysis aims to determine if the number of RUs is adequate for the number of people living in the locations of interest. In this study, we also used data from the Brazilian Radiotherapy Census (MS, 2019) which provided the number of teletherapy, or external beam radiation therapy (EBRT) units. The minimum amount of radiotherapy equipment per inhabitant is not exhaustive. Some studies consider 1 radiotherapy machine for every 300,000 inhabitants, as recommended by WHO (ONCOGUIA INSTITUTE, 2022) (Correa, 2019). Other researchers, such as Medenwald, Vordermark and Dietzel (2018), have carried out studies to determine the association between the number of radiotherapy treatment machines (RTMs) and the mortality rate for the types of cancer with the highest incidence in the population, including breast, prostate and lung. The analysis indicated a negative correlation with low density of radiotherapy equipment, but high

mortality rate. The models indicated a minimum density of approximately 30 RTMs per 10,000,000 inhabitants, or 1 RTM for 333,333.33 inhabitants, a value close to that considered by Oncoguia and Correa, as recommended by WHO. For the present study, we used a baseline of 1 RTM for every 300,000 inhabitants. The data presented in Table 3 compares the existing average quantity with our baseline.

Table 3: Correlation between the average number of radiotherapy devices available by region of the country (MS, 2019) and the quantity recommended by the WHO per 300,000 inhabitants, according to Oncoguia (ONCOGUIA INSTITUTE, 2022) and Correa (CORREA, 2019), as well as the difference between them.

Region of Brazil	Existing equipment by state	Quantity of devices recommended by the WHO	Difference between them
North	13	62	-49
Northeast	39	191	-152
Central-West	21	58	-37
Southeast	135	295	-160
South	51	103	-52
TOTAL	**259**	**709**	**-450**

Source: Author's own elaboration

Negative values of the differences between the existing quantities and the recommended quantities (Table 3) mean that the quantity of existing radiotherapy equipment is lower than the recommended quantity. In Table 3, we can see that the Southeast region has the largest deficit based on the WHO recommendation, while the Central-West region has the smallest deficit, which may seem like a paradox, considering the absolute numbers. Nationally, the deficit stands at 450 machines. It is important to highlight that in this paper, we consider each device to correspond to one facility, as 67% of Brazilian services operate only one machine, according to SBRT (2020).

It is worth noting that this study did not consider the normal wear and tear on electronic equipment, which would eventually lead to obsolescence and required replacement.

From Table 3, which shows the variability of the data, we can determine the degree of association between the "Number of existing devices" and "Number of devices recommended by the WHO" by regions of Brazil, using the Contingency Coefficient (C) (Eq. 2), which measures the association between two categorical variables, based on the chi-square statistic, with values ranging from 0 (no association) to 1 (perfect association) (Bussab; Morettin, 2004) (Montgomery; Runger, 2021).

$$C = \sqrt{\frac{\chi^2}{\chi^2+n}}\ \text{, (Eq. 2)}$$

where n is the total number of observations, in this case, the 5 regions of Brazil, and χ^2 is the measure of the overall distance between the variables (Eq. 3), defined as

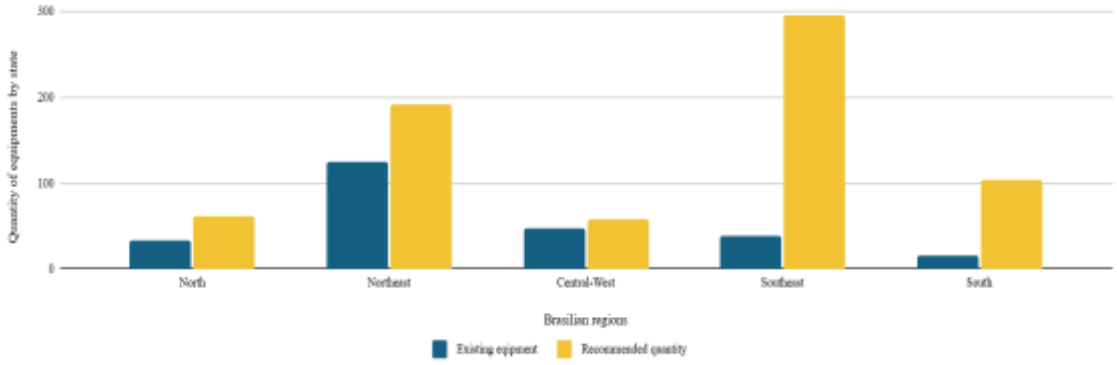
$$\chi^2 = \sum_i \sum_j \frac{(o_{ij}-e_{ij})^2}{e_{ij}}\text{, (Eq. 3)}$$

where o_{ij} represents the observed frequency, and e_{ij} represents the frequency recommended by WHO.

Based on these equations, we have a degree of association between the variables of 0.99, a very high degree of association since 1 is perfect association. This factor indicates that the quantity of existing equipment is highly related to the federated regions of the country, which is expected, given the difference in quantity of equipment and population density between them. However, other regional factors contribute to a very high degree of association, and further investigation of the determinants is necessary.

Graph 2 and Figure 1 show the breakdown of scenery by states.

Graph 2: Comparison of existing equipment by regions (blue) versus WHO recommendation (yellow).



Source: Author's own elaboration

We observed that no state in Brazil has the number of RTMs recommended by WHO. The state with the greatest deficit is Bahia, which is located in the Northeast region, followed by the state of Minas Gerais in the Southeast region, as well as Pernambuco, also in the Northeast region. Once again, the states of Roraima and Amapá stand out for the complete lack of radiotherapy equipment.

For a better visualization of the national panorama, Figure 1 illustrates the percentage of existing facilities in each Brazilian state in comparison to the number of RTMs recommended by WHO. The state in green has at least 60% of the target number of facilities with this service, whereas the states in yellow have between 40-59% of the target number, and the states in red have less than 39% of the target number, according to the Radiotherapy Census (MS, 2019).

Figure 1: General mapping of the number of radiotherapy devices in Brazil in relation to the ideal quantity by state.

Source: Author's own elaboration

The panorama presented in Figure 1 becomes even more worrying considering the regionalism of each state since the devices and services are not distributed homogeneously among Brazilian regions.

It is important to draw an interesting parallel between the North and Central-West regions. While the populations of these regions are similar in number, they have completely different capability for meeting the treatment needs of their inhabitants. This can be explained by the fact that the Central-West is home to the national capital

of Brasília in the Federal District. In other words, we can infer that the political and economic influence of the region is the distinguishing factor for the greater access to services in this location. It is also worth noting that the Federal District is the only unit of the federation that has the minimum quantity of RUs (60%) to meet population demands, or a percentage about 80% of the necessary installed capacity.

It is important to highlight that, within the Southeast region, the high number of machines and their distribution to inland cities are observed only in São Paulo, Minas Gerais, and Rio de Janeiro, whereas Espírito Santo shows a similar pattern to the rest of the country, with few services and most of them concentrated in the capital region.

FINAL CONSIDERATIONS

Based on the data and analyses carried out, Brazil, from a regional and state perspective, has a number of radiotherapy services well below the target established by WHO, with the majority of states (16) not reaching even 50% of the ideal number of RUs for their number of inhabitants. It is necessary, of course, to make the distinction that not all cases of neoplasia are indicated for radiotherapy treatment and, therefore, the analyses were made based on the recommendations of the World Health Organization (Correa, 2019).

One of the most notable factors is the discrepancy in the number of records given for radiotherapy services available in Brazil, especially considering that all the agencies consulted are official government sources. We also observed a high degree of variability in the data from different institutions. Despite the differences, the data from SBRT and CNEN are more similar, while the Ministry of Health is the least reliable, reporting fewer services than the other agencies. This fact alone is worrying since it is the source most widely known and, therefore, the one most consulted by the general population for reliable information. It is important to highlight that the aforementioned agencies update their records at different times. SBRT records were posted in 2016. The Ministry of Health updated its records in 2022, and records from CNEN, which is the most up-to-date source, were updated in 2024. However, even considering the temporality, it is still worrying that the Ministry of Health records are less current than a survey carried out six years earlier by SBRT.

Also, among the sources consulted during the preparation of this work, no distinction was made between public and private services; private services may be provided by the SUS. CNEN is the agency responsible for authorizations, supervision and inspection, among other functions, related to the use of nuclear energy in Brazil.

Radiotherapy units that are in the process of authorization by CNEN were also not considered.

It is important to highlight the work of the High Complexity Care Units (UNACONS), which are services that serve the population diagnosed with neoplasms, some of which are responsible for offering radiotherapy. They are present in all states and are extremely important, especially for the percentage of cases that do not require this type of treatment and can be treated in these facilities, which represents a positive sign for Brazilian public health.

In addition, the Radiotherapy Expansion Plan of the SUS is a Federal Government project that began in 2012 and is currently underway. This plan, which aims to improve the capacity to serve the Brazilian population, had completed 61 of the 100 planned solutions by July 2024 (MS, 2024) (MS, 2012).

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