Prioritizing locations for radiotherapy equipment at the national level: a policy-level case study of Brazil.

Keywords: Cancer, LINAC, Radiotherapy, Traveled Distances, Accessibility

Objective: Like many other low-middle income countries (LMICs), there is a major shortfall in radiotherapy (RT) services in Brazil. Here we assess the LINAC distribution, cancer incidence, the correlation with distance to RT and develop a tool to support prioritization of new LINAC distribution in Brazil.

Material and methods: Using the Brazilian Ministry of Health official reports, LINAC numbers and geographic distribution based on cancer incidence/needs were estimated in all Brazilian regions and states. A LINAC shortage index (LS index) was calculated as a relative measure of LINAC demand compared to supply (LS index: new cancer cases for RT / (LINAC number)/450 x 100). A prioritization framework considering the LS index, cancer incidence, and geographic factors was built (LS index = 100, the radiotherapy need is equal to the supply; LS index with values of 150 represents 50% LINAC shortage). Finally, using public cancer registry data from the Fundação Oncocentro de São Paulo (FOSP), and Google maps, the geospatial distance from home to RT was estimated for cancer patients treated with RT in São Paulo during 2005-2014.

Results: The number of LINACS was inadequate (below WHO suggested numbers) in all BR-regions. The number of new cancer cases for RT in the public health system/LINAC/year for each BR-region was 1410 in North (N), 1068 in Northeast (NE), 1466 in Middle west (MW), 945 in Southeast (SE), and 865 in South (S) ($p=0.09$). The LS index was higher in MW 326, N 313, and NE 237 BR-regions, and comparatively lower in SE 210 and S 192, indicating a high demand for RT compared to supply. There was a strong association between higher LS index and a greater number of patients who traveled to receive radiotherapy ($p<0.0001$). Patients living in MW (493 miles), N (1762 miles), and NE (1501 miles) traveled significantly longer average distances to receive RT in Sao Paulo ($p=0.03$). The reduced number of LINAC in these regions was associated with longer distance travelled ($p=0.03$).

Conclusion: There is significant discordance between distribution of cancer cases and LINAC availability in Brazil. The LS index was associated with the number of patients who traveled, and the LINAC number with the need to travel longer distances to receive RT. Based on the LS index, we developed a tool to help prioritize the development of RT infrastructure across Brazil; this approach may be useful in other health systems.

Introduction

Cancer is one of the major non-communicable diseases in Brazil with an estimated 625,000 new cases per year; from 2012 to 2020 cancer incidence has increased 18.5% [1,2]. Brazil is the largest country in South America, with a population of about 210 million. It is formed by 26 states and 1 federal district which are divided into 5 regions. The Southeast (SE), Northeast (NE) and the South (S) are the most populated with 89, 57 and 30 million people, respectively. The country covers a massive landmass with complex and challenging natural barriers to access areas located in the rainforest or next to major waterways.

Radiotherapy (RT) plays a pivotal role in management of cancers that are endemic in Brazil (i.e. prostate, breast, and lung [3,4]) where it has a substantial impact on clinical outcomes [4-6]. In Brazil, 80% of the RT is delivered in the public health system (Sistema Unico de Saude, SUS) which also serves about 80% of Brazil's total population (211 million people) [7,8]. Brazil has 363 LINACs, with 252 dedicated to the SUS and 111 to the private sector, unevenly distributed across the country [9].

In 2018 it was estimated that more than 100,00 patients lack access to RT (no LINAC capacity available) across Brazil [6]. Due to the heterogeneous distribution of RT services (**Figure 1 and 2** – majority of LINAC concentrated in the state of São Paulo), many patients are forced to travel long distances to access care (i.e, travel from rural to urban region). Long travel distance may impact on treatment choice [10-13], the RT modality offered [14-18], survival rates [19] and financial wellbeing.

São Paulo is the wealthiest and most populated (44 million people, 20% of the national population) state with 32% of the LINACs in the country (116/363 linacs) and 27% of all LINACS available within the public healthcare system (68/252 linacs) [9]. The disproportionately high availability of LINACs in the region attracts thousands of patients every year who travel long distances from other states to receive radiation treatment. To address both the shortfall and geographic coverage in 2012 the Brazilian government designed a national plan to acquire and install 80-100 RT LINACs in a 3 year timeframe [20]. However, the Ministry of Health 2019 RT census reported that only 8 of these LINACs were installed, and several of these LINACS were established in regions with comparatively lower LINAC shortages [9].

To aid future strategic planning for RT in Brazil, we performed a cross-sectional study using data from official National reports and a public database of patients treated in the State of São Paulo. Firstly, we aimed to develop a tool (LINAC shortage index (LS Index)) to evaluate RT services' distribution and capacity and to assess the Brazilian LINAC shortage. The LS index was planned based on Brazilian social inequalities such as lack of RT capacity and the need for long-distance travel to access RT treatment. Thus, the LS index was developed to improve policy and RT capacity planning and expansion in Brazil, in addition, to serve as a model to other countries. Secondly, we aimed to assess the impact of the LS index using real-world data. We examined the correlations between the LS index and traveled distances and LS index and access to RT using the state of São Paulo as the benchmark.

Material and methods

Data was extracted from the Fundação Oncocentro de São Paulo (FOSP) public database of the Cancer Hospital Registry (RHC) of the State of São Paulo (last assessed on February 02, 2021 - http://www.fosp.saude.sp.gov.br)[21]. The registry maintains (since 01/01/2005), a prospective populational database of all hospital and oncology departments in Sao Paulo

State, Brazil [21]. Patient level detail included basic demographics (sex, age), cancer type, clinical-stage, treatment, health insurance status, treatment center, vital status, province of residence and RT treatment location. Patients were categorized according to five Brazilian regions of origin: North (N), Northeast (NE), Midwest (MW), South (S), and Southeast (SE).

The number of new cancer cases in Brazil for 2020 was extracted from the National Cancer Institute (INCA) 2020 official database [2], and the number of LINACs in each state and region from the Ministry of Health 2019 RT census, **figure 1** [9].

When developing our model, we assumed that 50% of all newly diagnosed patients would need RT at some point in their disease trajectory based on previous needs assessments [3-6], and 80% of patients being treated in the public system [7,8]. Based on these estimates, the number of patients from SUS who would require the radiotherapy 'new cases for RT' was calculated using the formula: (Incidence of cancer x 80%) x 50%. Then, the number of cancer patients estimated to need RT, named 'new cases for RT' was divided by the number of LINAC in each state (27 in total) and Brazilian regions of origin: North (N), Northeast (NE), Midwest (MW), South (S), and Southeast (SE).

To estimate the areas with the highest LINAC deficit, and to prioritize which states and regions require further investment in new RT centers, the LINAC shortage index (LS index) was developed. In addition, the annual number of patients reasonably treated per year per LINAC was 450, defined based on Zubizarreta et al [21]. With these data, the LS index was calculated with the number of new cases in the SUS for RT/ (number of LINACs in the area)/450) multiplied by 100. For instance, in a region with an LS index = 100, the radiotherapy need is equal to the supply. Consequently, the LS index with values of 150 and 220 represents 50% and 120% LINAC shortages, respectively.

The difference between the LS index and the Zubirarreta et al RT capacity tool is that with the LS index we could rank the regions and states in a priority list considering the number of existing linacs and new cancer cases [21]. In addition, the LS index was analyzed in contrast with sociodemographic indicators of inadequate access to healthcare, like the need to travel to another state (SP) to receive RT and the distance (km) to the nearest RT center [21].

Based on the new RT cases, and per state LINAC shortage number, we developed a prioritization scheme and applied it to Brazilian states and regions. The prioritization criteria were devised based on principles of geographic and social equity [21]. Recognizing these principles, the LS index was designed as followed:

1- States with no LINACS were considered a top priority, and the cancer incidence was used to rank them. In the case of comparable cancer incidence (difference of up to 500 cases), the average distance travelled for all patients were used to rank.

2- States with at least 1 LINAC installed were ranked according to the LS index, and in cases with equal LS index, the cancer incidence was used to rank, and if the cancer incidence had a difference of up to 500 cases/year, the traveled distances were employed to rank.

To evaluate the correlation of the LS index with distance to RT, the patient data was extracted from the public database of the Cancer Hospital Registry (RHC) of the State of São Paulo [22]. The registry holds data on cancer patients' treatment since 01/01/2005 [22]. Patient level detail included basic demographics (sex, age), cancer type, clinical-stage, treatment, health insurance status, treatment center, vital status, province of residence and RT treatment location. Patients were categorized according to five Brazilian regions of origin: North (N), Northeast (NE), Midwest (MW), South (S), and Southeast (SE).

To determine travel distance (the distance from the city of origin and the RT facility) we applied the Euclidean method within the Google maps platform. We used the state of São

Paulo as the benchmark (defined as a standard or point of reference against which things were compared) as it has the highest number of LINACs, cancer incidence and hosts the FOSP RHC cancer registry. The São Paulo state FOSP RHC database includes information on 529,178 cancer patients treated in the state of Sao Paulo between January 2005 and December 2014 (last assessed on February 02, 2021 - http://www.fosp.saude.sp.gov.br).

As the state of São Paulo is in the SE region and due to the proximity with other three Brazilians states, an additional and separate analysis of the SE region was also performed. In this analysis, we considered the distance travelled by the São Paulo cancer patients within the state of São Paulo. We based the analysis on the assumption that rural and less populated areas of the state of São Paulo face under-supply of LINACS to treat cancer patients.

Statistical analysis

Continuous variables were treated by mean and standard deviations. Categorical variables were estimated by percentage. The association between the LINAC shortage, the number of patients treated outside of their origin and the long distances traveled was tested by linear regression. To compare the mean values of distance traveled, new cancer cases for RT, and LS index between the regions the Kruskall-Wallis test was used. The correlation Spearman test was used in the regression analysis, with a p value < 0.05 considered significant for linearity and R^2 indicating the strength of the association. R2 > 75% was indicative of a very strong association. All statistical analysis was performed with SPSS version 24.

Results

As of 2021, the absolute number of LINAC machines (and as a % of total) and new cancer cases per region was 128 (51.0%), 53(21%), 51(20.0%), 13(5.0%), and 7(3.0%) for SE, S, NE, MW and North, respectively. The number of new cancer cases per region were around 302,000, 115,000, 136,000, 48,000 and 25,000 for SE, S, NE, MW and North, respectively**; figure 1 (map representation)**. The descriptions of new cancer cases, the need for radiotherapy, the number and distribution of LINAC according to the Brazilian regions, and the LS index are presented in **table 1**.

The LS index ranged from 192 to 326, with the MW and N regions with the highest indexes and lowest access to RT treatment. The number of new cases for RT/year (p=0.001), LINAC number (p=0.008) and travelled distance (p=0.03) were significantly different among the different regions as presented on **table 1**. Conversely, the LS index values (p=0.48), and new cancer cases for RT/LINAC (p=0.09) were not.

The FOSP RHC registry patient demographics were summarized and presented at **table 2 (online only)**. According to the database, only 23% of the patients (n = 123,206) received radiotherapy (RT) as part of their cancer treatment, and the state of São Paulo, as expected, was the most common case origin accounting for 113,552 patients, followed by (number of patients who travelled from other Brazilian-regions to receive treatment in the state of São Paulo) Southeast region with 3,942 cases, Midwest 3,215 cases, North 1,472 cases, Northeast 647 cases, South 327 cases, and other countries 51 cases. Patients from other states accounted for 9,603 (7.8%) of the 123,206 RT patients. RT treated patient demographics were summarized and presented at **table 2 (online only).**

The LS index and the number of LINACs in each state was associated with the number of patients treated outside of the origin state (p=0.0001) and distance travelled (p=0.032) to receive RT, respectively. **Figure 3a and 3b**. **Figure 3 c** shows the direct correlation between the number of LINAC in different regions (p=0.001; state of SP excluded) and patients treated in the state of SP. Finally, a national RT priority table based on the number of LINACs, cancer incidence, travelled distance, and LS index was derived for all 27 Brazilian states, **table 3**. When defining priority, it is essential to recognize that four states (Tocantins, Acre, Amapa, and Roraima) in the North region did not have any RT LINAC serving the Brazilian public system (SUS) in 2019**, table 3**. These 4 states were ranked as the highest priority, based on the principles aforementioned. The remaining 23 states were ranked according to the criteria previously presented, **table 3**. Considering the regions in our prioritization table, Midwest and North were ranked as first and second regions based on the urgent need to expand RT capacity, **table 1**. The LS index established the rank order with no need to use the cancer incidence in 92.5% (25/27 states).

Discussion

LINAC capacity alone is not an ideal metric in a country with geographically dispersed populations such as Brazil. Thus, here present the LS index, based on LINAC distribution and the geographic distribution of new cancer cases needing access to RT. The LS Index is a metric aiming to improve equity in accessibility to RT

In order to improve efficiency and equity in health technology access, the use of real-world data, demographic and evidence-based medicine concepts are imperative to support the careful application of limited federal resources. Understanding the geographic distribution of LINACS in Brazil and their relationship to regional cancer incidence as well as cancer treatment center distribution per se allows for an opportunity to evaluate areas lacking RT capacity and prioritize regional investment.

Building on previous work from Zubizarreta et al (suggesting 450 new cancer cases /LINAC/ per year as for a developing country), we built a LS index [21]. We believe that the LS index (new cancer cases for RT/LINAC)/450) is more appropriate than new cancer cases/ LINAC for several reasons. First, it provides a measure of the degree of undersupply (or oversupply) of LINACs relative to regional cancer incidence. Second, it was strongly associated with the number of people who travel long distances, which has a very large impact on patients. Third, the LS index could help policymakers define RT expansion priorities, considering that the LS index may be easier to understand than new cancer cases per LINAC. For example, a LS index=130 should be understood as a 30% deficit from benchmark baseline. This means that there are 585 patients per LINAC instead of 450 from the benchmark. The target from a policy perspective would be achieving a LS index =100 or lower. Regions with LS index close or below to 100 do not require immediate investment. Accordingly, regions with a higher LS index should be prioritized. Thus, the present study is the one of the first in a series of steps to plan LINAC distribution for adequate cancer care.

Our study shows that in Brazil LINACs are not uniformly distributed and do not adequately cover the Brazilian demand or achieve equitable geographic access (based on cancer incidence). Patients treated in the state of São Paulo from Brazilian regions with the most limited RT capacity travelled the longest distances to receive RT treatment.

Creating tools to aid geographic prioritisation in RT procurement is crucial to ensure fairness and equity in outcomes. As it stands the distribution of RT in Brazil fails both tests of equity and distributive fairness [23,24]. The SE region has significantly more LINACs compared to other regions with nearly 50% of Brazil's total RT capacity. However, even with the high number of machines, the LS Index in the SE was 210 (ideally it should be 100), and not significantly different from other regions, **table 1**. In other words, there is not enough LINAC capacity anywhere (i.e. lack of capacity in regions with a lower cancer incidence of cancer and not enough LINACs in regions with higher cancer incidence), **table 1**. Our data reinforce the historical reflection that the implementation of radiotherapy services has not been data driven.

In emerging economies, such as Brazil, with a limited health budget and access to care, regional LINACs concentration can correlate with diminished access to standard care cancer treatment and/or increased financial toxicity (due to travel). The excessive number of cancer cases/ LINAC (>850) and the LS index (>190) in all regions, even in states with a lower cancer incidence, supported at least in part our assumptions, **table 1**. Our data showed that a higher LS index was associated with a large number of cancer patients treated outside of their origin; our data shows that about 10% of patients treated with RT in Sao Paulo are from outside the region. The possible explanation is that regions with a higher LS Index have longer waiting times compared to other regions; this leads to patients travelling to large urban centers with more RT machines and capacity to absorb the demand. This referral process was possibly aggravated with the publication of the SUS 60 days law from May 2013, which decreed that patients with cancer must start their cancer treatment within 60 days of diagnosis [6-8]. The law is well-intentioned, but without infrastructure and a uniform distribution of LINACs, it compels physicians to send their patients to other regions for timely treatments.

Comparing the Brazilian LINAC expansion plan progress with our LS index priority list, a significant lack of correlation is evident. After reviewing the official data from the Ministry of Health from 2019, none of the top 10 states for priority per our LS index received or had a new LINAC in operation. According to the Brazilian RT Census from 2019, only 8 new RT centres were active**.** The location of theses 8 RT centers which received a LINAC, were: 5 in the NE (1 Paraiba, 1 Sergipe, 1 Bahia, 1 Alagoas and 1 Ceará), 1 in the MW (Distrito Federal), 1 in the S (Parana) and 1 in the SE (São Paulo), **table 4**. However, on our prioritization framework, the NE states with installed LINACs were ranked as 18°, 23°, 22°,27° and 16º, **table 4**. The States from the MW, S, and SE ranked as 14°, 24°, and 20°, **table 4**. Thus, it is evident that our framework would have provided useful information for high level policy decisions regarding RT capacity distribution.

It is also crucial to explain that the LS index establishes the order to start taking action, and it does not necessarily mean that the LS index needs to achieve 100 to pass to another region, especially when the LS index is high across the country. The region North was ranked in our framework as the top priority because four states do not have any machine to treat their patients. Our analysis clarifies that beyond a profound distributive inequality for RT across the country with a severe lack of LINAC per se, the government policy for addressing this issue is not evidence-based. For instance, after 8 years from the beginning of the expansion plan, none of the states in the north region, where there is more shortage in the country, received a LINAC. The underinvestment and maldistribution with the Brazilian government RT policies have run counter to provision, thus forcing many patients into expensive and arduous journeys to access RT and potentially achieving suboptimal clinical outcomes. To the best of our knowledge, LS is a new tool that highlights RT infrastructure capacity deficits and makes priorities that will lead to the most patient reaching the best possible outcomes. Besides, the index can be applied for other developing countries facing similar either iniquity or inequity problems to improve the RT network, reducing LINAC shortages and barriers to access RT.

Our study findings should be interpreted in light of methodologic limitations. Several forms of bias can occur due to the nature and design of our study and analysis plan which is based on a retrospective population database. These limitations include, and are not limited to, imperfect availability of patient and RT capacity (based on the minister of health reports) data that could influence the development of the LS index. Moreover, the FOSP database considers patients from Sao Paulo State, limiting our ability to reproduce the analysis on other states and limiting the generalizability of our findings to the rest of the country. However, this is expected to be of limited significance, as Sao Paulo is the most populated and prosperous state in and on where most patients travel for advanced care. Additionally, the assumptions applied to our model (demand and supply) are not perfect and the numbers might vary among different regions (i.e., radiation utilization rates and or number or cases per LINAC). However, we believe this can also be seen as a strength of our work as the LS is simple enough that that these variables can be modelled in different scenarios to allow planning to be context specific

Conclusion

There is serious distributive inequality for RT access across Brazil, with the LINAC capacity inadequate to the cancer incidence. This geographical maldistribution forces cancer patients into expensive and arduous journals to access RT. Although the Brazilian government's RT expansion plan has been created to mitigate these distortions, it is not guided by evidence-based data. LS index is a new tool to highlight RT infrastructure capacity deficits and establish priorities for expanding RT capacity. This tool can be helpful to correct the underinvestment and maldistribution with the government treatment policies that have run over the last decades. Our data fill a gap and benefit equitably planning cancer services in Brazil and potentially in other countries facing similar problems.

Table and figure legends

Table 1 Characteristics of new cancer cases, number and distribution of LINAC in the Brazil regions.

Table 2 (on line) Characteristics of the FOSP patient's data including in the analysis.

Table 3 Radiotherapy priority scale based on the local need for increased RT capacity accounting for current LINAC capacity in the SUS, cancer incidence, LINAC shortage index and average traveled distance in kilometers.

Table 4 List of centers concluded per State, Region, date of conclusion and priority order considering the LS index.

Figure 1 Brazil map showing the distribution and the cancer incidence in the regions.

Figure 2 Brazil map showing the number of patients treated outside the state of origin and the average distance to the RT center.

Figure 3(a) The LS index and Number of patients from each region treated outside of origin state; (b) LINAC number in each state and traveled distance; (c) LINAC number and traveled distance in the Southwest region.

References

1) Estimative 2012 – Cancer Incidence in Brazil. Available from: http://portal.saude.sp.gov.br/resources/ses/perfil/gestor/homepage/estimativas-de-incidencia-de-cancer-2012/estimativas_incidencia_cancer_2012.pdf
2) Estimate 2020 – Cancer Incidence in Brazil. Available from: https://www.inca.gov.br/sites/ufu.sti.inca.local/files//media/document//estimativa-2020-incidencia-de-cancer-no-brasil.pdf
3) Delaney G, Jacob S, Featherstone C, Barton M. The role of radiotherapy in cancer treatment: estimating optimal utilization from a review of evidence-based clinical guidelines. Cancer. 2005 Sep 15;104(6):1129-37. doi: 10.1002/cncr.21324. Erratum in: Cancer. 2006 Aug 1;107(3):660.

4) Atun R, Jaffray DA, Barton MB, Bray F, Baumann M, Vikram B, Hanna TP, Knaul FM, Lievens Y, Lui TY, Milosevic M, O'Sullivan B, Rodin DL, Rosenblatt E, Van Dyk J, Yap ML, Zubizarreta E, Gospodarowicz M. Expanding global access to radiotherapy. Lancet Oncol. 2015 Sep;16(10):1153-86. doi: 10.1016/S1470-2045(15)00222-3.

5) Hanna TP, Shafiq J, Delaney GP, Vinod SK, Thompson SR, Barton MB. The population benefit of evidence-based radiotherapy: 5-Year local control and overall survival benefits. Radiother Oncol. 2018 Feb;126(2):191-197. doi: 10.1016/j.radonc.2017.11.004.

6) Mendez LC, Moraes FY, Fernandes GDS, Weltman E. Cancer Deaths due to Lack of Universal Access to Radiotherapy in the Brazilian Public Health System. Clin Oncol (R Coll Radiol). 2018 Jan;30(1):e29-e36. doi: 10.1016/j.clon.2017.09.003.

7) Weltman E, Marta GN. Radiotherapy and the SUS: A collapse foretold. Rev Assoc Med Bras (1992). 2017 Feb;63(2):93-94. doi: 10.1590/1806-9282.63.02.93.

8) Moraes FY, Marta GN, Hanna SA, Leite ET, Ferrigno R, da Silva JL, Carvalho Hde A. Brazil's Challenges and Opportunities. Int J Radiat Oncol Biol Phys. 2015 Jul 15;92(4):707-12. doi: 10.1016/j.ijrobp.2014.12.063.

9) Censo Radioterapia. Relatório. Ministério da Saúde, Secretaria de Atenção Especializada à Saúde, Departamento de Atenção Especializada e Temática. 26 de Julho de 2019. Available from: https://www.saude.gov.br/images/pdf/2019/julho/26/paper-radioterapia-ALT3.pdf

10) Athas WF, Adams-Cameron M, Hunt WC, Amir-Fazli A, Key CR. Travel distance to radiation therapy and receipt of radiotherapy following breast-conserving surgery. J Natl Cancer Inst. 2000 Feb 2;92(3):269-71. doi: 10.1093/jnci/92.3.269.

11) Nattinger AB, Kneusel RT, Hoffmann RG, Gilligan MA. Relationship of distance from a radiotherapy facility and initial breast cancer treatment. J Natl Cancer Inst. 2001 Sep 5;93(17):1344-6. doi: 10.1093/jnci/93.17.1344.

12) Celaya MO, Rees JR, Gibson JJ, Riddle BL, Greenberg ER. Travel distance and season of diagnosis affect treatment choices for women with early-stage breast cancer in a predominantly rural population (United States). Cancer Causes Control. 2006 Aug;17(6):851-6. doi: 10.1007/s10552-006-0025-7.

13) Aggarwal A, Lewis D, Sujenthiran A, et al. Hospital Quality Factors Influencing the Mobility of Patients for Radical Prostate Cancer Radiation Therapy: A National Population-Based Study. *Int J Radiat Oncol Biol Phys*. 2017 Dec 1;99(5):1261-1270. doi: 10.1016/j.ijrobp.2017.08.018.

14) Mackillop WJ, Groome PA, Zhang-Solomons J, Zhou Y, Feldman-Stewart D, Paszat L, Dixon P, Holowaty EJ, Cummings BJ. Does a centralized radiotherapy system provide adequate access to care? J Clin Oncol. 1997 Mar;15(3):1261-71. doi: 10.1200/JCO.1997.15.3.1261.

15) Pagano E, Di Cuonzo D, Bona C, Baldi I, Gabriele P, Ricardi U, Rotta P, Bertetto O, Appiano S, Merletti F, Segnan N, Ciccone G. Accessibility as a major determinant of radiotherapy underutilization: a population based study. Health Policy. 2007 Mar;80(3):483-91. doi: 10.1016/j.healthpol.2006.05.006.

16) Punglia RS, Weeks JC, Neville BA, Earle CC. Effect of distance to radiation treatment facility on use of radiation therapy after mastectomy in elderly women. Int J Radiat Oncol Biol Phys. 2006 Sep 1;66(1):56-63. doi: 10.1016/j.ijrobp.2006.03.059.

17) Liu E, Santibáñez P, Puterman ML, Weber L, Ma X, Sauré A, Olivotto IA, Halperin R, French J, Tyldesley S. A Quantitative Analysis of the Relationship Between Radiation Therapy Use and Travel Time. Int J Radiat Oncol Biol Phys. 2015 Nov 1;93(3):710-8. doi: 10.1016/j.ijrobp.2015.06.004.

18) Huang J, Wai ES, Lau F, Blood PA. Palliative radiotherapy utilization for cancer patients at end of life in British Columbia: retrospective cohort study. BMC Palliat Care. 2014 Nov 18;13(1):49. doi: 10.1186/1472-684X-13-49.

19) Baade PD, Dasgupta P, Aitken JF, Turrell G. Distance to the closest radiotherapy facility and survival after a diagnosis of rectal cancer in Queensland. Med J Aust. 2011 Sep 19;195(6):350-4. doi: 10.5694/mja10.11204.

20) Ministério da Saúde, PORTARIA Nº 931, DE 10 DE MAIO DE 2012. Institui o Plano de Expansão da Radioterapia no Sistema Único de Saúde (SUS). Available from: http://bvsms.saude.gov.br/bvs/saudelegis/gm/2012/prt0931_10_05_2012.html

21) Zubizarreta EH, Fidarova E, Healy B, Rosenblatt E. Need for radiotherapy in low and middle income countries – the silent crisis continues. Clin Oncol (R Coll Radiol). 2015 Feb;27(2):107-14. doi: 10.1016/j.clon.2014.10.006.

22) Fundação Oncocentro de São Paulo (FOSP), Registro Hospitalar de Câncer (RHC). Base de dados do RHC, available at: http://200.144.1.68/cgi-bin/dh?rhc/rhc-geral.def Access in Feb 02, 2021.

23) Olsen JA. Concepts of Equity and Fairness in Health and Health Care. The Oxford Handbook of Health Economics. doi:10.1093/oxfordhb/9780199238828.013.0034

24) Emanuel EJ, Persad G, Upshur R, et al. Fair Allocation of Scarce Medical Resources in the Time of Covid-19. New England Journal of Medicine. 2020;382(21):2049-2055. doi:10.1056/NEJMsb2005114