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Natural environmental gamma radiation exposure and prevalence of breast cancer in Poços de Caldas, MG, Brazil

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► ***Short report***

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ABSTRACT

Background: Environmental ionizing radiation has been associated with increased cancer risk by several studies. The Brazilian city of Poços de Caldas, MG, seats on a huge deposit of uranium, which was until recently mined. We performed a retrospective analysis of 310 cases of patients with breast cancer, who were exposed for at least ten years to different levels of ionizing radiation around their homes, to verify whether a correlation existed between disease incidence, prevalence, and exposure. ***Materials and Methods***: Gamma radiation was measured on the roads and the urban street grid. We retrieved the clinical files of 310 patients from the Population-Based Cancer Registry of Poços de Caldas city, MG, Brazil and compared the local prevalence and incidence of breast cancer per city district to the local effective doses. ***Results:*** Effective doses of radiation around patients' homes varied from 0.72 and 1.30 mSv/year, with 70% of the homes exposed to doses $\geq$ 1.0 mSv/year. When considered the number of cases in the study in relation to the adult female population of the city, the incidence of female breast cancer was 25.9% higher than the national average incidence for the same period, 2003-2011 (68.32/100,000 versus 50.61/100,000 respectively). ***Conclusion:*** The higher incidence of breast cancer among the adult female population of Poços de Caldas may be associated with chronic exposure for ten or more years to effective doses equal or slightly above the international reference dose of 1.0 mSv/year. Other known risk factors for breast cancer in our patients were not different from those found nationwide.

Keywords: *Gamma radiation, breast cancer risk, cancer registry, environmental radioactivity.*

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INTRODUCTION

Cancer is the second cause of death from disease in Brazil, and there is a significant variability in mortality rates among the Brazilian regions, mostly in association with social and lifestyles, tobacco abuse, diet, obesity, endemic viral infections as well as occupational or environmental exposure to carcinogens (1,2). The Brazilian estimates for 2014-2015 were 576,000 new cases of cancer, including non-melanoma skin cancer, which highlights the public health burden posed by cancer to the country. Female breast cancer incidence in 2016 is estimated in 56.9 new cases per 100,000 women (2) and they represent 50.8% of the population (106,757,903 women) (3). Among the inhabitants of Poços de Caldas city, MG, Brazil, there is a general concern regarding the possibility of higher cancer risks, due to the presence of rich uranium deposits and gamma radiation hotspots across the plateau upon which the city was built. The main goal of the present study was to verify if there was a correlation between female breast cancer prevalence and incidence and the effective doses of gamma radiation in certain areas of Poços de Caldas City, in the State of Minas Gerais, Brazil.

Ionizing radiation is considered a risk factor for cancer due to its potential to induce the stochastic effect, e.g., DNA damage, especially in rapidly cell-cycling tissues, such as the epithelial and endocrine tissues, in addition to immune and stem cells (2,4). Gamma radiation can alter biologic molecules through direct or indirect mechanisms. Direct mechanisms involve interactions between molecular atoms present in DNA molecules or other cell components, thus causing chemical changes due to ionization (5, 6). IARC has classified ionizing radiation as a Group 1 carcinogen, based on the studies of populations that survived nuclear accidental exposure (Chernobyl, 1986 and Fukushima, 2012) or nuclear attacks (Hiroshima and Nagasaki, 1945) (7). Many human populations around the world are chronically exposed to non -lethal doses of natural gamma radiation, radon gas, and radon progeny. The lack of conclusive data in many epidemiologic studies on the increased risks posed by radiation does not imply a risk-free situation (8), including in the case of breast cancer (9).

The region known as the Poços de Caldas Plateau is located in the southwest of the Minas Gerais State, Brazil, and has a geologic history associated with a volcano, that was extinct 60 million years ago, when it collapsed into a magmatic caldera. The present plateau upon the caldera displays radioactive anomalies in specific geographic locations, with radiation doses above those normally registered on the earth surface (10).

MATERIALS AND METHODS

The study used a quantitative approach, which analyzed the clinical files of 310 women with a positive diagnosis of malignant breast lesions, detected between 2003 and 2011. The data source was the City Population-Based Cancer Registry at the Department of Epidemiologic Surveillance. Therefore, it is a retrospective, open, non-randomized study of an observed scenario. The city was divided in five regions (e.g., districts) and the respective population (men, women and children) was as follows: South, 51,195; West: 12,615; East: 39,816; North (Central District): 45,096 inhabitants. Figure 1 shows the distribution of patients' homes in the four city districts. The total adult female population, older than 24 years comprised 50,268 women, according to the Brazilian Institute of Geography and Statistics (IBGE) 2010 census. The estimation of the effective dose was obtained by measuring gamma radiation originating from the ground along the entire roads and street grid of the region, according to the roadmap issued by the city administration and the IBGE (3).

Gamma radiation was measured with the gamma detector Thermo-Eberline FHT 1376 MobiSys, manufactured by Thermo Eberline, LLC. GmbH, Germany. The FHT 1376 model consists of a 5 liters plastic scintillation detector and a Global Position System (GPS). The system can record gamma radiation doses along with the local spatial coordinates of each reading. These devices are stored in a special case to be easily transported inside a vehicle. Along with a computer and an antenna, the system needs to be supplied with an external voltage of 12 V. The system allows that gamma dose rate measurements and spatial coordinates to be recorded once every second through the software MobiSys (11).

Those measurements were performed by the Plateau Project of Pocos de Caldas (10), with which our research was jointly developed. We measured the effective dose (H) of gamma radiation in the urban street grid and adjacent access roads using the SI unit Sievert (Sv), wherein 1 Sv equals 1 J kg^{-1} (1 J kg^{-1} = 1 Gray, and 1 rem = 0.01 Sv). Effective dose (E) is by definition the dosimetric quantity for the overall impact of radiation on radiosensitive tissues or organs, expressed by the formula $E = \Sigma_T W_t H_T$, where H_T is the equivalent dose in tissue T and W_T is the tissue weighting factor. Both, the effective dose and the equivalent dose of ionizing radiation, refer to non-lethal doses that may contribute to the onset of degenerative diseases and loss of life expectancy, over the

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years (12).

The collected data were coded and recorded in the computerized database using Microsoft Office Excel ® software. The data were presented in frequency and percentage for categorical variables and means, and standard deviations for continuous variables. We used an Excel spreadsheet data to make estimates of proportions and their variability in the formulations for a cluster sampling in two stages. Descriptive statistical analysis was performed (mean, frequency and percentages) using Excel 2013 program (Microsoft Corporation, USA), with which was calculated prevalence. Female breast cancer prevalence for the period 2003-2011 was calculated by dividing the number of breast cancer cases per district by its total adult female population, equal or older than 24; and also by dividing the total number of cases in the period by the total adult female population of the city.

The nationwide annual incidence of breast cancer per 100,000 women, between 2003 and 2011, was collected from the Instituto Nacional de Cancer (INCa) database (2) and compared to the incidence in the city adult female population, adjusted per 100,000 women, to compare the average incidence of both databases.

We have also compared effective doses per district with the number of patients living in that area and calculated the breast cancer prevalence per district in relation to its respective adult female population older than 24 years. Demographic data was extracted from the national and municipal census (3). Also, we compared the national incidence of female breast cancer between 2003 and 2011 (DATASUS - INCa) with the data found in the city for the same period, taking into consideration the known risk factors (other than radiation) as well. The percentage of female breast cancer patients exposed to each range of effective radiation in the city was also calculated.

Before data collection, the research project was submitted to the Ethics Commission of the School of Medical Sciences at Universidad Estadual de Campinas (FCM-UNICAMP), receiving approval in compliance with the Brazilian CONEP's Federal Law 466/2012.

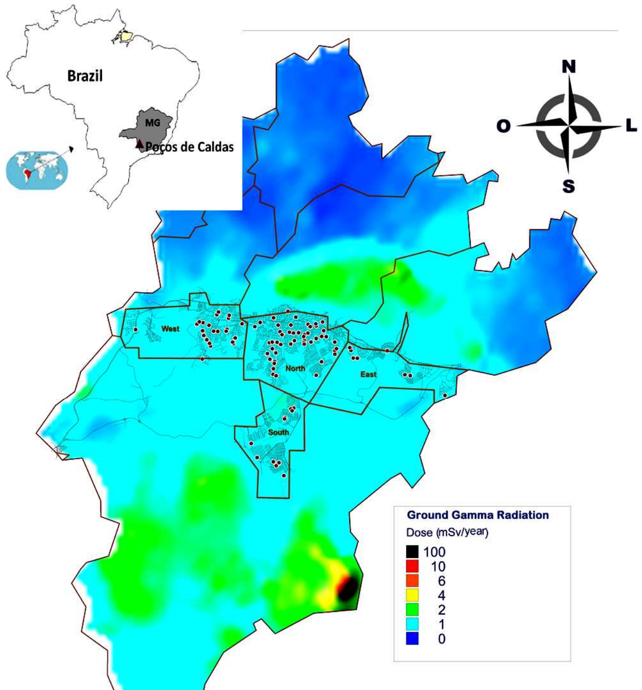

Figure 1. Location of sampling organized by district in Poços de Caldas city, Minas Gerais state, Brazil.

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RESULTS

Table 1 shows the number of patients' homes in the four city districts and the local effective doses detected. It also shows the prevalence and risk of breast cancer per 1,000 adult women in each district. The total female population, older than 24 years, living in the urban districts, was 50,268 and the median risk of breast cancer was 7.695/1,000 women. The Southern District had 47 homes of patients, and the median annual effective dose was 1.092mSv (min. 0.82mSv and max.1.26 mSV). The Western District harbored 60 homes, with the median annual dose of 0.91 mSv. (min 0.71 mSv and max 1.09 mSv); the Eastern had 79 patients homes and the median effective annual dose of 0.91 (min 0.8 mSV and max. 1.17mSv); the Northern (Downtown) included 124 homes of patients and median annual effective dose 0.94mSv (min. 0.72mSv and max. 1.17mSv). The prevalence of breast cancer cases per adult women population of each city district between 2003 and 2011 was, respectively: South, 47 cases/17,304; West, 60 cases/4,264; East, 79 cases/13.458; and North, 124 cases/15,242.

The overall median effective dose for the 310 breast cancer cases was 0.91 mSV/year. Figure 1 shows effective doses varying from 96mSv/year (red segments) in the rural hotspots, to values below 1 mSv/year in some urban areas. In the city streets, the predominant range of effective doses was between 1 and 3mSv/year (green segments) or ≤1mSv/year (blue segments).

The ground gamma radiation in the areas in which 70% of the patients lived was mostly between 1 mSv and 1.26 mSv/year, with the percentage of patients living under different doses of natural gamma radiation in the city shown in figure 2. The median emission was 0.954 mSv/year with deviation value of 0.114 mSv/year (11.4 mrem/year).

The median age of patients at diagnosis was 58.9 years with a minimum age 24 and maximum 94. Overall, the collected data have shown that the majority of breast cancer cases was diagnosed in patients ranging from 41 to 60 years of age, representing 67.5% of the affected women.

Table 1. Per district distribution of breast cancer cases and respective female population older than 24 years, the breast cancer prevalence rates, and the effective gamma radiation dises. (*) The total female population older than 24 years, living in the urban districts, was 50,268 and the median risk of breste cancer was 7.695/1,000 women older than 25 years. Population data was based on census IBGE 2010.

Urban District	Number (n) of Patients	Female Population Age ≥25 years (*) (IBGE 2010)	Breast Cancer Prevalence	Radiation Levels	Effective Dose mSv/year
South	47	17,304	0,0027	Minimum	0,82
			2.71/1000	Median	1,092
				Maximum	1,26
West	60	4,264	0,0140	Minimum	0,71
			14.07/1000	Median	0,91
				Maximum	1,09
East	79	13,458	0,058	Minimum	0,8
			5.87/1000	Median	0,91
				Maximum	1,17
North (Center)	124	15,242	0,008	Minimum	0,72
			8.13/1000	Median	0,94
				Maximum	1,17

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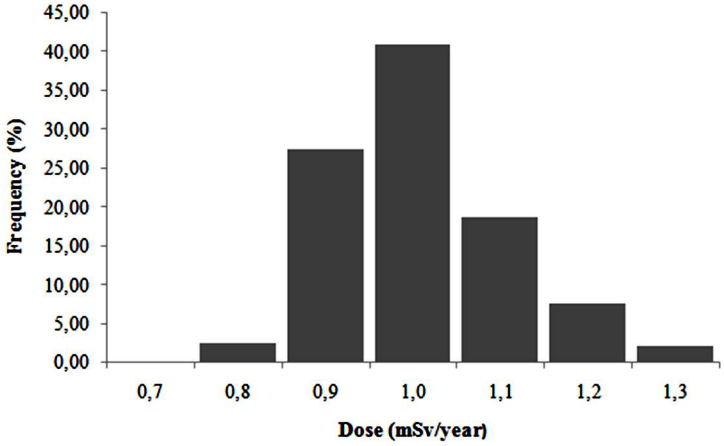

Figure 2. Percentage of patients living under different effective doses of natural gamma radiation in the city.

DISCUSSION

The median effective dose of 0.954mSv/year from our study was higher than the UNSCEAR (13) reference dose of 1mSV/year. The International Atomic Energy Agency (14) emphasizes that, ideally, population exposure to natural sources of ionizing radiation should be kept under the effective reference dose (1mSv/year) and when it is not possible, remediation measures should be taken by the local authorities. In the vicinity of the patients' homes, we have found annual effective doses that varied from 0.72 mSv to 1.26 mSv. However, 70% was exposed to effective doses equal to or higher than the UNSCEAR reference dose. The estimated median prevalence of breast cancer in the adult female population was 7.695/1,000 women, for the period 2003-2011. The adjusted average incidence per 100,000 adult female inhabitants was 68.32 new cases per year, whereas the national average incidence for the same period was 50.61 new cases per year (2). Therefore, the incidence in the city was 25.9% higher than the national average for the same period. Moreover, the city number of new female breast cancer cases between 2007-2011 was 258, equivalent to 65.76 new cases per 100,000 women, according to data published by the INCa in 2015 (2).

The known risk factors for breast cancer in our study (other than radiation), were not different than the ones found in the national epidemiologic studies of breast cancer. The only possible additional risk factor was the chronic exposure for 10 years or longer to levels of natural ionizing radiation equal or higher than the reference dose.

The first studies of the sort conducted in Italy (15) and Poland (16) have found significant correlations between radiation exposure and increased incidence of cancer, whereas other studies in India (17) and Ireland (18) did not. The same is true of more recent studies, including that by Shahbazi-Gahrouei in 2003 (19) and Taeb *et al*. in 6458 (20). It is not improbable that stable populational groups which have been exposed to high levels of natural ionizing radiation over several generations may have undergone adaptive survival mutations, such as radio resistance, whereas other groups, more recently introduced in such environments, have not. Molecular epidemiology may also explain such differences, because radio adaptative mutations may take place in some populations but not in other groups, due the presence of single-nucleotide polymorphisms (SNPs).

CONCLUSION

In this article, we have considered only the possible impact on the prevalence and incidence of female breast cancer of exposure to environmental gamma radiation for ten or more years. Our group is also assessing the results of indoor radon measurements in the patients' homes, which were not herewith included. We

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hope that the ongoing analysis of tumor subtypes and other breast cancer molecular features and indoor radon may bring some new light on the reasons for such differences in incidence rates in Poços de Caldas, despite the patients' exposure to doses only discretely higher than the international reference one.

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Conflicts of interest: *Declared none.*

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