




Cancer incidence in the cohort exposed to Cesium-137 accident in Goiânia (Brazil) in 1987

Incidência de câncer na coorte exposta ao Césio-137 de Goiânia (Brasil) em 1987

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Abstract

Objective: to describe the incidence of cancer cases in the direct victims of the accident, Groups I and II, and compare with overall cancer incidence rates for the population of Goiânia. **Method:** A descriptive study is presented herein, on the cohort of patients directly exposed and contaminated (Groups I and II) during the cesium-137 accident, which occurred in Goiania (Midwest Brazil) in 1987. The incident cases of malignant neoplasms diagnosed between 1988 and 2017 are described. Analysis included calculation of the Incidence Rate Ratio (IRR) with 95% confidence intervals (CI95%), according to gender. **Results:** In the 30-year period (1987-2017) following individual exposure, there were seven cancer cases in six directly exposed victims of the cesium-137 accident. Of these, five neoplasms occurred in men, in the esophagus (1), prostate (3), bladder (1), and two in women, involving breast cancer (1) and skin melanoma (1). The accumulated incidence rates in the direct victims of the Cesium-137 accident were 327.9/100,000 for men and 148.6/100,000 for women. For the overall population of Goiânia, rates were 221.4/100,000 and 231.2/100,000 in men and women, respectively. The ratios of brute incidence rates (direct victims of Cesium-137/population of Goiânia) were 1.5 (IC95%:0.4;5.9) in men and 0.6 (IC95%:0.1;3.8) in women, with no statistically significant differences. **Conclusion:** Cancer incidence in the direct victims of the Cesium-137 accident (Groups I and II), according to sex, was not different from the incidence in those not exposed to Cesium-137 in the municipality of Goiânia. Cancer risk was similar to that of the general population of the municipality of Goiânia.

Key words: Cesium-137. Radiation. Exposure. Risk. Cancer. Incidence. Brazil.

Resumo

Objetivo: descrever a incidência de casos de câncer nas vítimas diretas do acidente Grupo I e II e comparar com as taxas de incidência de câncer na população de Goiânia. **Método:** Estudo descritivo da coorte de pacientes diretamente expostos e contaminados (Grupos I e II), no acidente com Césio 137, ocorrido em Goiânia (Brasil), em 1987. Descrevemos os casos incidentes de neoplasia maligna diagnosticados no período entre 1988 e 2017. Foram calculados a razão das taxas de incidência e os intervalos de confiança de 95% (IC95%), segundo o sexo na população de estudo. **Resultados:** No período de 30 anos (1987-2017), ocorreram sete casos de câncer, em seis vítimas diretas do acidente pelo césio-137. Desses, cinco ocorreram em homens (esôfago [1], próstata [3] e bexiga [1]) e dois, em mulheres (mama [1] e melanoma da pele [1]). As taxas de incidência acumulada nas vítimas diretas do Césio-137 foram de 327,9/100,000 entre homens e de 148,6/100,000 entre as mulheres. Na população de Goiânia, as taxas foram de 221,4/100,000 e 231,2/100,000 em homens e mulheres, respectivamente. As razões das taxas de incidência bruta (vítimas diretas do Césio-137/população de Goiânia) foram 1,5 (IC95%:0,4;5,9) em homens e 0,6 (IC95%:0,1;3,8) em mulheres, não houve diferenças estatisticamente significativas. **Conclusão:** A incidência de câncer nas vítimas diretas do acidente pelo Césio 137 (Grupos I e II), segundo o sexo, não foi diferente da população não exposta ao Césio-137 do município de Goiânia; portanto, o risco de câncer foi semelhante ao da população geral do Município de Goiânia.

Palavras-chave: Césio-137. Exposição à Radiação. Risco. Câncer. Incidência. Brasil.

INTRODUCTION

In September, 1987, two men removed a radioactive source from an abandoned radiotherapy clinic in Goiania, Central Brazil. The source was broken, divided into pieces and sold to a local junk-yard¹⁻⁵. The content of the source was Cesium-137, a result of the fission of uranium 235 in laboratory settings. Most of Cesium decays by beta emission to meta stable barium, which is responsible for all gamma ray emissions in samples of Cesium-137. Cesium-137 has a physical half-life of 30.17 years⁶⁻⁷.

The Cesium-137 source involved in the accident contained 28 grams of the element and 63 grams of agglutinant material. The estimated activity was 2000 Curies (74 Terabecquerel). Approximately 19.26 grams of Cesium were dispersed during the accident, over a 3000 m² area of Goiania, resulting in nine highly contaminated sites. A total of 3500 m³ of radioactive waste were produced and stored in a specially built site in the city of Abadia de Goiás¹⁻⁵.

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As a consequence of this exposure and contamination, 249 people were considered direct victims of the accident (radio-accidented). Radio-accidented individuals were stratified in follow-up groups according to their degree of exposure and contamination: Group I (GI), Group II (GII) and Group III (GIII). GIII was constituted by indirectly involved neighbors, family and workers, which are not the focus of this study.

After the accident, four victims died due to acute radiation syndrome (ARS). Studies carried out in the first years after the accident evidenced unstable chromosomal mutations in direct victims⁸⁻¹². The accident caused psychosocial impacts on direct victims and on the general population of Goiânia^{1,13}, with negative effects on life quality.

Population-Based Cancer Registries (PBCR) are the main tool to monitor cancer incidence, through incidence rates, over time¹⁴. The PCBR of Goiânia was created in 1986, and has been registering the new cancer cases that occur in the municipality of Goiânia. Incidence rates are published in the CI5 series since volume VI^{15,16}.

In Groups I and II, exposure to radiation could trigger carcinogenesis due to the stochastic effects associated with increases in genomic instability¹⁷⁻¹⁹, inducing the occurrence of malignant neoplasms¹¹. Herein the incident cancer cases in groups I and II (patients exposed and contaminated with known levels) are described, followed by a comparison with the risk of developing cancer in the non-exposed population of Goiânia, throughout a 30-year period.

METHODS

A descriptive study is presented herein, carried out with data from the cohort of patients exposed to cesium-137, classified in Group I (GI) and Group II (GII). GI consists of individuals that developed the Acute Radiation Syndrome (ARS) and/or Local Radiation Injuries (LRI) and all other individuals with a cytogenetically estimated whole-body absorbed dose of ≥ 0.2 Gy or a Cesium-137 internal burden $\geq \frac{1}{2}$ the Annual Limit on Intake (ALI) for radionuclides. In GI, 28 patients presented multiple or single LRI on the face, upper body and feet. Two male and two female ARS patients died about 40 days after their initial radiation exposures. GII is constituted of individuals that presented no acute effects of radiation exposure but presented exposures or internal burdens ≤ 0.2 Gy or $\leq \frac{1}{2}$ the ALI for cesium-137⁵.

A total of 102 patients were monitored: 56 patients (31 men) aged between 02-51 years old belonged to GI; 46 patients (22 men) aged between 7 months-59 years old belonged to GII. Five men and one woman of GI and one woman of GII deceased due to causes unrelated to neoplasms (external cause [years 2008, 2012, 2014], cardiogenic [2014] and neurogenic shock [2016], pneumonia [2016], undefined [2006]) (unavailable data). Therefore, in the 30-year period (1987-2017), 53 men were

monitored (1525 person years) along with 49 women (1345 person years).

Since 1987, GI and GII patients have been monitored on an out-patient basis protocol at the Radio-Accidented Assistance Center (C.A.RA,) from the Secretary of Health of the State of Goiás (SES/GO). During the first three years there were monthly appointments, which then took place every four or six months, or according to specific requirements. The medical follow-up protocol included routine physical evaluation, biochemistry analysis, serologic tests, imaging exams (e.g., abdominal and cervical ultrasound, gastric endoscopy, mammograms, PSA, colpocytology) and other tests, as necessary²⁰⁻²².

Monitoring of the cohort (GI and GII) enabled identification of the number of persons-time exposed and the risk of cancer. The incident cancer cases were identified in these groups (GI and GII), in two 15-year periods (1987-2002 and 2003-2017) and for the entire period (1987-2017). Incidence rates were calculated for GI and GII and for the non-exposed population of the municipality of Goiânia, according to sex and time periods.

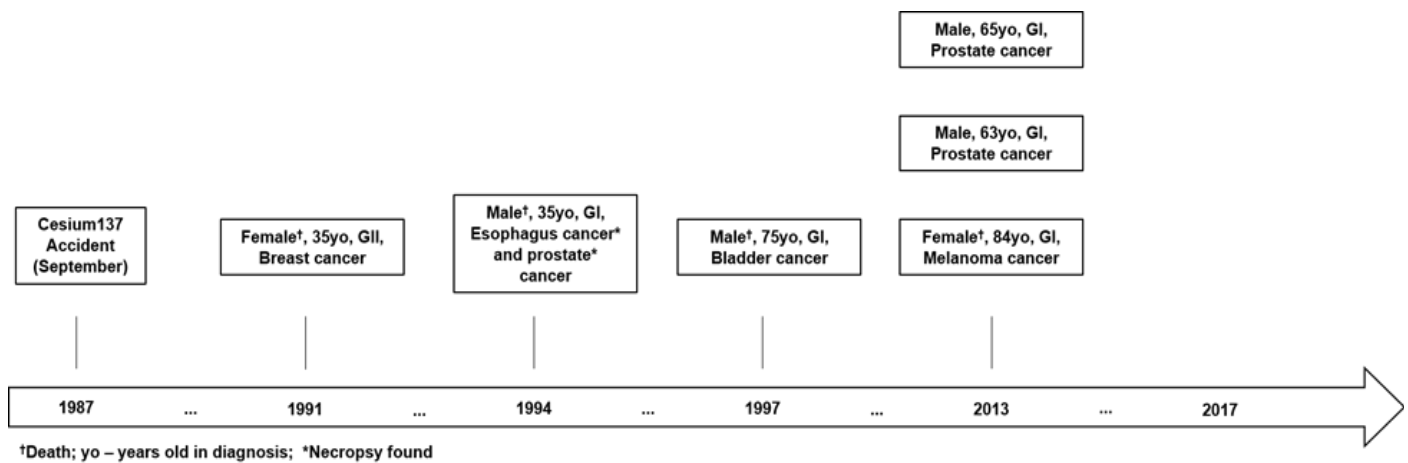
Incidence rates were calculated for the municipality of Goiania, available at <http://www2.inca.gov.br/wps/wcm/connect/estatisticas/site/home/rcbp/>, in two 15-year periods. The number of expected cases was estimated by applying the mean incidence rate for each sex and period. The Incidence Rate Ratio (IRR) and the 95% confidence intervals (CI95%) were calculated with the epitools package²³, to obtain incidence rates for the exposed and non-exposed individuals of the municipality of Goiania.

All ethical research principles were considered and this study was approved by the National Commission on Research Ethics (CONEP) in July, 2004 (document n. 982 CONEP/CNS/MS).

RESULTS

In Group I, the cancer cases identified were: esophagus and prostate cancer in one patient (autopsy, 1994), bladder squamous cell carcinoma (1997), and skin melanoma in the lower limbs (2013). In Group II, one breast cancer case progressed to death (1991). Thirty years after the cesium-137 accident, in GI, six cancer cases were verified in five of the exposed individuals (years 1994, 1997 and 2013): five cases in men (esophagus [1], prostate [3], and bladder [1]) and one case in a woman (melanoma [1]). The median age of these patients was 65 years (35-84 [minimum-maximum]). In GII, one breast cancer case was identified (1991) in a 35-year old woman (Figure 1).

Between 1988 and 2017, the incidence rates of Groups I and II were 327.9/100,000 in men and 148.6/100,000 in women. For the municipality of Goiânia, the rates were 221.4/100,000 and 231.2/100,000 in men and women, respectively. There is a cancer development risk of 1.5 for men (CI95%:0.4;5.9) and 0.6 for women (CI95%:0.1;3.8). There was no difference regarding the studied periods (Table 1).

Figure 1. Cancer cases incidence in GI/GII victims of Cesium 137 accident in thirty years period, 1988-2017.**Table 1.** Incidence Rate ratio (IRR) of Cancer in GI/GII victims of Cesium-137 accident versus observed cancer incidence in Goiânia (Brazil) from 1988 to 2017.

| Period | Gender | Cancer incidence | | Cancer cases in victims | | IRR (CI95%) |
|-----------|--------|------------------|-----------------------|-------------------------|----------|----------------|
| | | In victims | In general population | Observed | Expected | |
| 1988-2002 | Male | 383,1 | 152,6 | 3 | 1.2 | 2.5 (0.3;21.1) |
| | Female | 148,1 | 168,2 | 1 | 1.1 | 0.9 (0.1;12.9) |
| 2003-2017 | Male | 269,5 | 298,1 | 2 | 2.2 | 0.9 (0.1;6.1) |
| | Female | 149,0 | 236,4 | 1 | 1.6 | 0.6 (0.1;7.7) |
| 1988-2017 | Male | 327,9 | 221,4 | 5 | 3.4 | 1.5 (0.4;5.9) |
| | Female | 148,6 | 231,2 | 2 | 3.1 | 0.6 (0.1;3.8) |

DISCUSSION

Carcinogenesis is a multistep process that is followed by genetic alterations, where the effects of radiation can be modified by other physical or chemical agents²⁴⁻²⁶. This can be mediated by different mechanisms and depends on the type of tissue and dose exposure^{7,27-29}. Exposure to ionizing radiation can damage DNA and result in mutation and consequent development of cancer^{2,30}.

As to the breast cancer described in 1991, studies at Chernobyl evidenced could be at higher risks of developing breast cancer even if exposed to low doses of radiation³¹⁻³³. However, the presence of mutated genes, such as BRAC1 and BRAC2, was not investigated in the breast cancer patient of 1991.

The number of incident cases in GI/II was not significantly different from the general population of the municipality of Goiânia, as verified when comparing the observed and expected incidence rates. This means that the risk of developing cancer in direct victims was similar to the risk of the overall population of the city of Goiania.

After five years of exposure to Cesium-137 at the Chernobyl accident, a discrete increase in cancer risk was observed³⁴. A higher risk (18%) was observed for the development

of solid neoplasms, between 1992 and 2009 [SIR: 1.18; 95%CI:1.15;1.22]³⁵. The incidence of thyroid cancer increased in children and adolescents five years after the Chernobyl accident. However, there were no incident thyroid cancer cases in Groups I/II registered during the 30 years of study, after the Goiânia accident.

Psychosocial effects after exposure to Cesium-137 were described subsequently to the Seoul accident, where risk perception was higher in older women, with lower education levels, and in the most exposed individuals³⁵. Therefore, risk communication must be further studied in victims of accidents with ionizing radiation³⁶.

The non-significant IRR found for GI/II in Goiânia could have been due to the group selected for this study, which encompassed individuals exposed to known doses, with known parameters of internal and external contamination; therefore, the results obtained herein are consistent. The cancers developed by the individuals exposed to Cesium-137 could have occurred due to other risk factors, such as lifestyle, including tobacco smoking, alcohol consumption, among others, similar to those observed in the general population of Goiania. Besides, five of the seven cases occurred in patients over the age of 60. Aging is a risk

factor for the development of neoplasms, either because of the prolonged exposure to risk factors or due to failures in DNA repair³⁷⁻³⁹.

A recent study that focused on those exposed to low radiation doses of Cesium-137 revealed that the children, of which at least one of the parents was directly exposed to ionizing radiation of Cesium-137, present higher mutation rates. Also, these children could have the germ line mutation, which remains for several generations. Copy number variation (CNV), and especially genomic losses, confirm that the biomarker of parent exposure can be inherited by children even when exposure rates are low⁴⁰.

GI/II have been monitored for the last 30 years. The monitoring protocol (routine consultations, tests) could have reduced the risk of developing neoplasms, as well as other chronic diseases. This is due to early diagnosis or treatment of pre-cancerous lesions, or even due to counseling on healthy lifestyle habits⁴¹.

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