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Ten Years Evaluation of the Relationship Between the Individual Dose of Hospital Workers Occupationally Exposed to X-Rays and its Leukocyte and Platelet Counts of the CBC Tests

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Abstract: The occupational health assessment of workers exposed to ionizing radiation is done through Complete Blood Count (CBC) tests in some countries, although studies have shown that this biomarker does not show evidence of exposition to low dose radiation. It is essential to analyze the radiation level doses of healthcare workers (HCW) exposed to X-rays in a university hospital and evaluate the association of this exposure on blood exam parameters. For this purpose, CBC tests and individual records of the X-rays exposure of 766 HCW were retrospectively evaluated from 2009 to 2019. Analyzing the annual and the monthly individual effective doses, no statistically significant relationship was identified with leukocyte count (b = -0.01 (95% CI, -0.03 - 0.01); p = 0.254) and (b = -0.04 (95% CI, -0.02 - 0.12); p = 0.606) respectively; nor for platelet count (b = -0.52 (95% CI, -1,09 - 0.05); p = 0.072) and (b = -0.69 (95% CI, -3.63 - 2.25); p = 0.646), respectively. Assessing the relationship between the monthly dose and the CBC tests, we found association with the leukocyte count (b = -0.12 (95% CI, -0.19 - -0.04); p = 0.002), but did not occur for platelet count (b = -1.91 (95% CI, -4.93 - 1.11); p = 0.215). The findings of the study demonstrated that there is no statistically significant relationship, with regard to clinical validity, between the individual effective doses and the leukocyte and platelet count in the CBC test in all analyses performed.

Keywords: Occupational Exposure, Radiation Dose, Blood Count, Radiology, Health Assessment.

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Dez anos de avaliação da relação entre a dose individual dos trabalhadores hospitalares ocupacionalmente expostos aos raios X e suas contagens de leucócitos e plaquetas dos exames de hemograma

Resumo: A avaliação da saúde ocupacional dos trabalhadores expostos à radiação ionizante é feita por meio de exames de hemograma completo em alguns países, embora estudos tenham demonstrado que esse biomarcador não apresenta evidências em exposições a baixas doses de radiação. É fundamental analisar os níveis de doses de radiação dos profissionais de saúde expostos aos raios X em um hospital universitário e avaliar a associação dessa exposição aos parâmetros dos exames de sangue. Para tanto, foram avaliados retrospectivamente exames de hemograma e registros individuais da exposição aos raios X de 766 profissionais de saúde no período de 2009 a 2019. Analisando as doses efetivas individuais anuais e mensais, não foi identificada relação estatisticamente significativa com a contagem de leucócitos (b = -0,01 (IC 95%, -0,03 - 0,01); p = 0,254) e (b = -0,04 (IC 95%, -0,02 - 0,12); p = 0,606) respectivamente; nem para contagem de plaquetas (b = -0,52 (IC 95%, -1,09 - 0,05); p = 0,072) e (b = -0,69 (IC 95%, -3,63 - 2,25); p = 0,646), respectivamente. Avaliando a relação entre a dose mensal e os exames de hemograma, encontramos associação com a contagem de leucócitos (b = -0,12 (IC 95%, -0,19 - -0,04); p = 0,002), mas não ocorreu para a contagem de plaquetas (b = -1,91 (IC 95%, -4,93 - 1,11); p = 0,215). Os achados do estudo demonstraram que não há relação estatisticamente significativa, no que diz respeito à validade clínica, entre as doses efetivas individuais e a contagem de leucócitos e plaquetas no hemograma em todas as análises realizadas.

Palavras-chave: Exposição Ocupacional, Dose de Radiação, Hemograma, Radiologia, Avaliação de Saúde.

1. INTRODUCTION

The medical use of radiation is considered the main responsible for human exposure to artificial radiation [1], occupational health risk due to healthcare workers (HCW) exposure to X-rays in the hospital environment remains a relevant topic.

The association between the ionizing radiation exposure and the induced biological effects was established based on the projections of existing data resulting from major accidents and catastrophes, such as the victims of the Chernobyl accident and of the World War II nuclear bombs [1]. However, the evidence is not conclusive for low dose radiation due to the occurrence of many associated effects on the metabolism of the human body caused by other physical or chemical agents [1,2]. There is considerable uncertainty as regards to the risks of cancer and radiation doses below 100 mSv, suggesting that further studies should be carried out to understand the basic mechanisms of low dose ionizing radiation and health hazard assessment [1,4,6].

The most important approach to quantifying radiation protection is the personal routine monitoring dosimetry. This physical dosimetry encounters several difficulties, such as the correct assessment of the effective dose and the assessment of the dose in the extremities and lens of the eyes [3]. On the other hand, there is a gap concerning the definition of health surveillance biomarkers for exposure to low doses of ionizing radiation [2]. Some countries in Latin America, Asia and Europe [4,5] adopt the Complete Blood Count (CBC) test as complementary exams and possible biomarkers that identify this exposure to ionizing radiation. The CBC test measures many different parts and features of blood, including the quantification of erythrocytes, leukocytes, and platelets. This test is used in health surveillance to characterize the general health of the worker and, also can detect a variety of disorders such as infections, anemia, diseases of the immune system, and blood cancers. As a consequence of their radiosensitivity and high cell renewal rate (from hours to days), leukocytes and platelets are blood components that could characterize possible damage due to exposure to ionizing radiation [1,6,7]. However, the CBC test is not the most suitable biomarker, as it requires doses over the limits established as safe to exposed workers by international organizations to damage the components of peripheral blood [8-10].

Studies on the effects of low dose X-ray exposure are not conclusive [1,2]. Difficulties concerning the necessary sample size, standardization of methodologies to collect data, among others, are limitations that need to be overcome [11]. The lack of evidence for a dose-response relationship between occupational exposure to X-rays in a hospital environment and the different health surveillance procedures in different countries led us to address this research question. Therefore, the aim of this study is to assess whether the radiation doses of HCW who perform the application of diagnostic and interventional X-rays are significant, concerning alteration in CBC tests, regarding the leukocyte and platelet count.

2. MATERIALS AND METHODS

This is retrospective cross-sectional observational research to evaluate workers' CBC tests, considering their leukocyte and platelet counts, in relation to the X-ray doses received by these subjects in the period from January 2009 to December 2019, in a university hospital in the city of Porto Alegre, in southern Brazil. CBC tests collected data and the individual radiation dose records of workers exposed to X-ray at the hospital were retrospectively analyzed in a sample of HCW consisting of physicians, nursing staff, radiographers, and other professionals. The risk characteristics of workers' exposure to X-ray is stratified by each type of routine work department. In order to facilitate the assessment, workers were divided into four major areas, brought together by the similarity of the type of equipment / procedure performed: Surgical (surgical center services, surgical teams from medical specialties such as cardiovascular, general, digestive, thoracic, pediatric, neurosurgery, nephrology, urology, orthopedics, pneumology and gastroenterology), Interventional (Cardiology, Neurology, Interventional Radiology and Endovascular Surgery), Diagnostic (Diagnostic Radiology, Medical Physics, Dentistry and Speech Therapy) and SAMPE (as described in Portuguese "Serviço de Anestesia e Medicina Perioperatória"). This is the team of anesthesiologists who work in all other areas). SAMPE professionals were treated separately as they also performed specific activities in the other three areas. Workers exposed to the risk of contamination with radioactive material were not included in the study, since aspects of internal dosimetry were not addressed. Professionals working in the departments of radiotherapy were also excluded to mitigate the confounding bias due to the differences in LET (Linear Energy Transfer) among all these ionizing radiations. Workers selected for the sample are instructed in their routine, through institutional training, to use Personal Protective Equipment (PPE) such as lead aprons, thyroid protectors, and lead glasses, when in a controlled area, wear their personal dosimeter on the lead apron at chest level to estimate Personal Dose Equivalent Hp (10). This study will treat individual dose assessments without considering the attenuation provided by PPE and, in simplified form, directly relating the Personal Equivalent Dose Hp (10) with the Personal Whole Body Effective Doses levels for individual dose sample stratification purposes.

Once the distribution of the monthly and annual effective doses of the HCW in their areas was known, the leukocyte and platelet count data were assessed for reference levels of effective dose (recording and investigation), as well as the average annual effective dose limit for these workers. The database was built based on the individual monthly doses of the workers, recorded at the university hospital's Human Resources information system from January 2009 to December 2019. CBC tests (biannual) data of each worker, specifically leukocytes and platelets, were collected through consulting occupational health records in the hospital information system. This information was merged and formatted with the aid of the SPSS® version 21 statistical package. This study was guided by the biostatistics team of the Hospital de Clínicas de Porto Alegre Research Board.

The results of occupational blood tests and radiation dose are described as quantitative variables, distributed by occupationally exposed workers, during the study period. The results of radiation dose were treated using three different variables: a twelve-month accumulated dose retroactive to the period of the last CBC test, a monthly dose of the same period of the CBC test and a monthly dose of the period immediately before the CBC test. Absolute and relative percentage frequencies were used to describe the frequency of examinations and subjects with a dose above the values established as the level of investigation for monthly dose (1 mSv) and annual dose limit of 20 mSv. In addition to statistical convenience, this is the dose limit established at the research institution as a primary trigger for occupational risk mitigation actions. Doses were not evaluated in relation to the maximum effective dose limit of 50 mSv in one year in this study. It is important to highlight that the ICRP recommends for occupational exposure, in planned exposure situations, that "the limit should be expressed as an effective dose of 20 mSv per year, averaged over defined 5 year periods (100 mSv in 5 years), with the further provision that the effective dose should not exceed 50 mSv in any single year"[17].

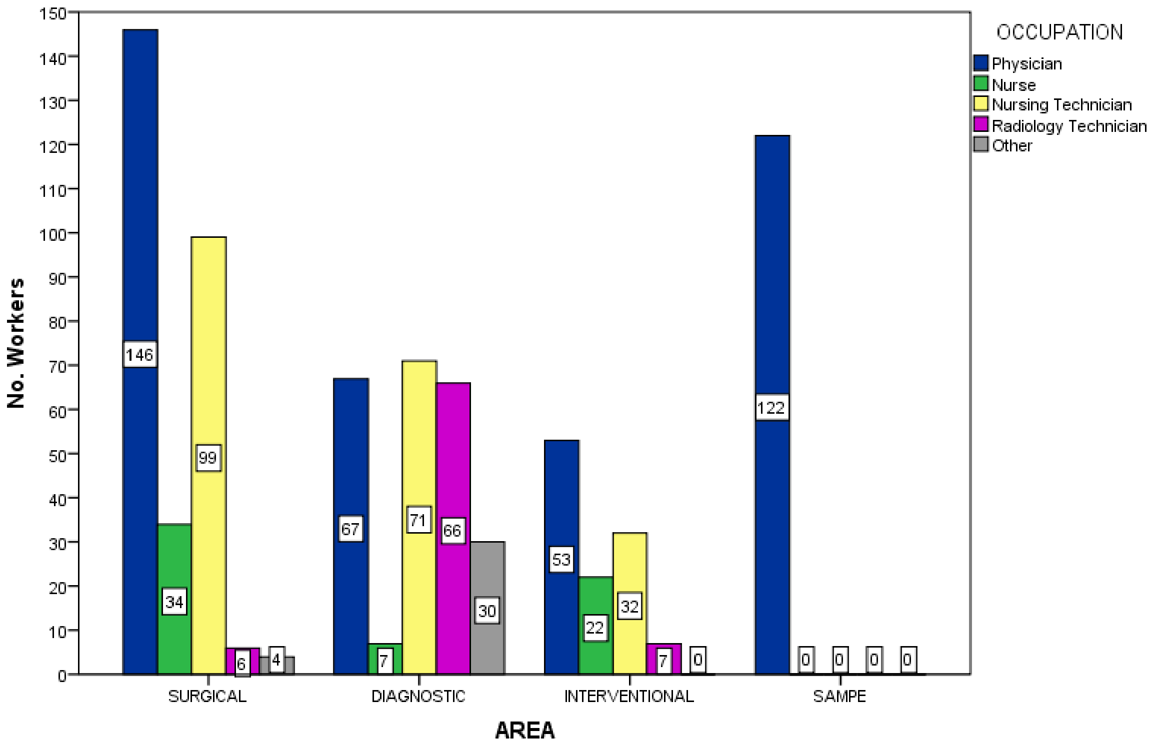
Sample observations are not independent and can often be correlated, such as dose measurements over time in the same individual or dose measurements obtained from individuals in the same area. In this way, the relationship between dose and leukocyte and platelet count values was evaluated using Generalized Estimating Equations (GEE), considering $p<0.05$ a statistically significant relationship. The tested equation is a linear regression where the response variable is the CBC test and the explanatory variable is the radiation dose. Linear distribution and robust estimation with an exchangeable working correlation matrix were used. The p-value is obtained using the Wald chi-square test.

3. RESULTS AND DISCUSSIONS

This study evaluated the individual records of the ionizing radiation exposure and the leukocyte and platelet count of 766 workers occupationally exposed to X-ray in a hospital environment, in the period from 2009 to 2019. Of these workers, 45.83% were physicians, 27.51% and 9.14% were nursing technicians and nurses respectively, 12.98% were radiographers, 1.41% were darkroom attendants, 1.21% were dental surgeons, 0.93% were medical physicists, 0.62% were perfusionists and 0.37% were speech therapists.

The sample distribution among the areas was 35.43% in the Surgical area, 33.68% in the Diagnostic area, 15.72% in the SAMPE area and 15.17% in the Interventional area. In Figure 1, this distribution is further demonstrated by the occupation performed by the worker.

Figure 1: Distribution of workers in each area by occupation. In the occupation defined as "Other" there are Perfusionists in the Surgical area, and in the Diagnostic area there are physicists, dental surgeons, speech therapists and darkroom attendants



Source: Author.

During the study period, 3,468 doses readings were observed above the recording level (0.2 mSv from 2009 to 2018, and 0.1 mSv in 2019) [11], that is, some monthly dose values, representing only 5.58% (95% CI, 5.41 - 5.77) of the total monthly doses, distributed in 319 workers (41.64%; 95% CI, 38.19 - 45.16). The descriptive values of the monthly and annual effective doses for this group, were distributed by area and occupation in Table 1.

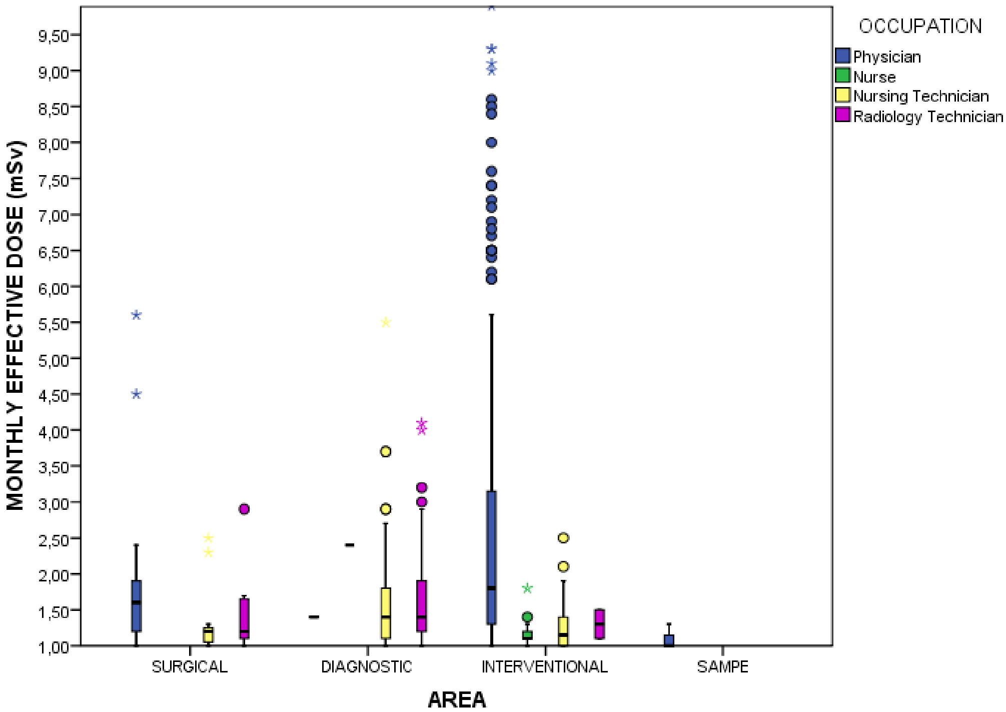
Table 1: Descriptive analysis of individual monthly and annual effective doses above the recording level, distributed by area and occupation

			MONTHLY EFFECTIVE DOSE (mSv)			ANNUAL EFFECTIVE DOSE (mSv)		
AREA	**OCCUPATION**	**Frequency**	**Median**	**Max**	**75thPerc**	**Median**	**Max**	**75thPerc**
SURGICAL	Physician	245	0.40	5.60	0.60	1.30	19.00	4.50
	Nurse	9	0.30	0.70	0.40	0.30	1.40	0.40
	Nursing Technician	111	0.30	2.50	0.50	0.60	5.40	1.80
	Radiology Technician	42	0.40	2.90	0.80	2.95	7.80	5.50
	Perfusionist	3	0.20	0.50	-	0.40	0.50	-
DIAGNOSTIC	Physician	52	0.30	1.40	0.40	1.35	4.10	3.65
	Nurse	12	0.40	2.40	0.55	0.50	2.40	0.90
	Nursing Technician	545	0.50	5.50	0.80	2.70	15.40	4.80
	Radiology Technician	484	0.40	4.10	0.90	2.20	17.60	6.15
	Medical Physicist	1	0.20	-	-	0.20	-	-
	Darkroom Attendant	7	0.20	1.70	1.70	0.50	1.70	1.70
	Dental Surgeon	2	0.25	0.30	-	0.25	0.30	-
	Speech Therapist	18	0.40	1.10	0.50	1.65	3.60	2.70
INTERVENTIONAL	Physician	719	0.80	24.40	1.60	7.60	120.60	13.30
	Nurse	445	0.40	1.80	0.60	3.10	8.30	4.40
	Nursing Technician	703	0.40	2.50	0.60	2.10	8.40	3.20
	Radiology Technician	5	0.90	1.50	1.10	1.50	3.40	2.30
SAMPE	Physician	65	0.30	1.30	0.50	0.50	3.80	1.20

In the period from 2009 to 2019, there were 121 workers with a monthly dose greater than or equal to 1 mSv, 15.80% (95% CI, 13.28 - 18.58) of the total workers evaluated, distributed in 641 monthly doses (1.03%; 95% CI, 0.95 - 1.12). Figure 2 illustrates the distribution of the monthly effective dose of workers that presented at least a monthly dose value greater than 1 mSv. Values of monthly effective doses greater than 10 mSv (11.8 to 24.4 mSv), a total of 10 values defined as outliers, were removed from the graph. All these data refer to monthly doses received by interventional physicians.

The median monthly doses above 1 mSv vary from 1.0 to 1.8 mSv, for a physician in the SAMPE area and for a physician in the Interventional area, respectively. The highest value found for the 75th percentile was 3.15 mSv, in the medical staff in the Interventional area, and the lowest was 1.2 mSv in the staff of nurses in the same area. Figure 2 also shows the monthly effective dose outliers of 2.4 mSv for the nursing staff and 1.4 mSv for the physician staff in the Diagnostic area, which were representative when analyzing the workers with a dose greater than 1 mSv. The occupation with the greatest dispersion of the monthly effective dose data was that of a physician in the Interventional area, with minimum monthly individual doses below the recording level and a maximum of 24.4 mSv.

Figure 2: Distribution of monthly effective doses of workers with doses of 1 to 10 mSv



Source: Author.

Assessing the values of the 12 months accumulated doses, in relation to the annual limit of 20 mSv, only six workers who received such a dose level were identified, that is, 0.78% (95% CI, 0.29 - 1.70) of the workers with annual effective doses above the limit established in the legislation. Of these, four work in the Interventional Radiology department and two in Interventional Cardiology - all of them working in the Interventional area. The highest cumulative dose record in 12 months was 120.6 mSv in the Interventional area. Table 2 summarizes the dose distribution data and their percentage.

Table 2: Distribution monthly and annual doses of workers and their percentages relative to total sample

	Nº monthly records	**Monthly Doses (%) (95%CI)**	**Nº of Workers**	**Workers (%) (95%CI)**
TOTAL SAMPLE	62,088	100.00	766	100.00
Monthly dose higher than the recording level (0.2/0.1 mSv)	3,468	5.58 (5.41 - 5.77)	319	41.64 (38.19 - 45.16)
Monthly dose equal to or greater than the level of investigation (1 mSv)	641	1.03 (0.95 - 1.12)	121	15.80 (13.28 - 18.58)
Accumulated dose in 12 months equal to or greater than the annual dose limit (20 mSv)	149	0.24 (0.20 - 0.28)	6	0.78 (0.29 - 1.70)

The study evaluated 5,968 complete blood tests, of 645 subjects. Regarding the normality reference for leukocyte count (from 3.6 to 11.0 x10^3/µL) and platelets (from 150 to 400 x10^3/µL), 5,768 blood count tests (96.6%; 95% CI, 96.16 - 97.09) reports were in accordance with the normal levels for leukocyte and platelet counts. Exactly 200 CBC tests showed variation with reference to the normality of the test, with 65 tests (1.09%; 95% CI, 0.84 - 1.39) below the lower limit for leukocyte count and 127 tests (2.13%; 95% CI, 1.78 - 2.53) below the lower limit for platelet count. 135 (2.26%; 95% CI, 1.90 - 2.67) exams for leukocyte count and 73 (1.22%; 95% CI, 0.96 - 1, 54) for platelet count were higher than the upper threshold of normality.

Analyzing the relationship between the accumulated dose in 12 months (annual) and the CBC tests, no statistically significant relationship was identified with leukocyte count (b = -0.01 (95% CI, -0.03 - 0.01); p = 0.254), nor with platelet count (b = -0.52 (95% CI, -1.09 - 0.05); p = 0.072).

Evaluating the association between the monthly dose and workers' blood tests, there is a statistically significant relationship with leukocyte count (b = -0.12 (95% CI, -0.19 - -0.04); p = 0.002), but not with platelet count (b = -1.91 (95% CI, - 4.93 - 1.11); p = 0.215). For a 1 mSv increase in the monthly dose, the leukocyte count would be reduced to 0.12 x 10^3 units/μL.

The association between the dose of the previous month to the CBC test and the leukocyte count in the sample showed a statistically non-significant relationship (b = -0.04 (95% CI, -0.02 - 0.12); p = 0.606), as well as for platelet count (b = -0.69 (95% CI, -3.63 - 2.25); p = 0.646).

The assessment regarding the probability of the monthly investigation level (1 mSv) and the annual effective dose limit, when reached or exceeded, may cause effects on peripheral blood as described in Table 3. From these relationships it is possible to observe that there is no statistically significant difference in relation to the averages of leukocytes or platelets. The exception is identified in the analysis of doses accumulated in 12 months (annual) that showed a statistically significant difference in relation to the average of leukocytes. However, the two groups (accumulated dose lower than 20 mSv and accumulated dose higher than or equal to 20 mSv) are within normal reference values for leukocyte count, and the average difference between these two groups is 1.22 x 10^3 units/μL (95% CI, 1.03 - 1.41).

Table 3: Statistical evaluation, using Generalized Estimation Equations (GEE), of the relationship between the individual dose and the results of CBC tests (leukocyte and platelet count)

	Leucocytes		**Platelets**	
	Mean (IC95%)	**P**	**Mean (IC95%)**	**P**
Accumulated Dose 12 months (annual)				
< 20 mSv	6.94 (6.83 - 7.05)	<0,001	249.97 (246.14-253.79)	0.298
≥ 20 mSv	5.73 (5.52 - 5.92)		235.41 (207.60-263.22)	
Monthly Dose - Month of CBC Test				
< 1mSv	6.94 (6.83 - 7.05)	0.728	249.96 (246.13 - 253.78)	0.433
≥ 1 mSv	6.87 (6.44 - 7.29)		246.60 (237.41 - 255.80)	
Monthly Dose - Month before CBC Test				
< 1 mSv	6.96 (6.84 - 7.07)	0.656	250.05 (246.18 - 253.93)	0.530
≥ 1 mSv	6.85 (6,39 - 7.32)		252.69 (243.57 - 261.81)	

The statistically identified exceptions occurred during the assessment of the monthly dose and of the leukocyte count, as well as during the assessment of the annual doses in relation to the difference in the average leukocyte count. When evaluating the monthly dose in relation to the leukocyte count, it is possible to equate that for a 1 mSv increase in the monthly dose it would reduce 0.12 x 10^3 /µL in the leukocyte count, with the upper limit of the confidence interval very close to zero, that is, possibly without variation in this count. The value of the loss of elements may be associated with the quantification process of the laboratory. According to Faillace [12], the coefficient of variation in the quantification of blood elements in automated cell counters, of the highest technology and subjected to periodic quality controls, is approximately 3% for counts above 2,000/µL, reaching up to 50% for counts below 1,000/µL, disregarding variations associated with sample collection/preparation and storage/transport. It was possible to identify a statistically significant difference in relation to the average of leukocytes in the groups of accumulated doses in 12 months lower than 20 mSv, or higher than or equal to 20 mSv. However, the two groups are within normal reference values for leukocyte count and the mean difference between the groups is 1.22 x $10^3/\mu L$ (95% CI, 1.03 - 1.41), not showing clinical significance. Therefore, the findings agree with Valverde et al. [13] and Cascón [10], who question the validity of the biannual evaluation by using CBC test in relation to its potential action for the health surveillance of the workers exposed to low radiation doses. According to these authors, from a technical point of view, the use of a deterministic characteristic indicator, that is, damage, is not justified to control workers exposure to ionizing radiation, since the limits established for physical dosimetry are much more conservative and are mostly not reached by occupationally exposed workers in their work routine [10,13]. The sample of effective monthly doses showed a 94.42% distribution of 62,088 dose readings from individuals that work in areas with exposure to X-rays in the hospital environment with monthly doses below the recording level (0.2/0.1 mSv) [11]. The evolution of the use of interventional radiology, guiding procedures or surgeries using fluoroscopy [14], were possible to be identified when the largest group of workers exposed to X-rays in a hospital environment was composed by physicians (45.83%), followed by the nursing team and technicians in radiology. Physicians in the interventional area had the highest frequency of doses above the record level (719), followed by nursing technicians who assist in the same area (703) and nursing technicians who work in the diagnostic area (545) assisting computed tomography exams and contrast examinations guided with fluoroscopy equipment. This is a reality described in the UNSCEAR reports [2,15] and in the BEIR VII Part 2 report [16].

As defined in national and international regulations [11,17,18], monthly doses equal to or greater than 1 mSv should be investigated to make possible to plan improvements in radiological protection so that the annual dose limit of 20 mSv is not reached. Considering only the study sample that showed a monthly effective dose reading above 1 mSv, 15.80% (95% CI, 13.28 - 18.58) of these workers evaluated, and 1.03% (95% CI, 0.95 - 1.12) of the monthly doses, presented a median ranging from 1.0 mSv for physicians in the SAMPE area and 1.8 mSv for physicians in the Interventional area. The highest doses of the SAMPE staff were received while these professionals were working in an interventional area. It was possible to verify a significant dispersion of the monthly effective dose values for physicians in the interventional area (minimum below the recording level and maximum of 24.4 mSv). The dispersion in the effective dose values of the interventional area is the result of the wide variation in protocols and processes in this area. Doses vary considerably according to the procedure, clinical complexity, patients, operator training and quality assurance of equipment and processes [15,19,20].

When observing the annual effective dose values in relation to the dose limit (20 mSv), only six workers received such a dose level, or 0.78% (95% CI, 0.29 - 1.70) of workers. Of these, four are active in the Interventional Radiology Unit and two in the Interventional Cardiology Unit. The highest record of accumulated dose in 12 months was 120.6 mSv, in the area of Interventional Radiology (Table 1). According to the International Commission on Radiological Protection (ICRP) [17], this case would be subject to a special investigation, and if it is identified as an effective dose, it must be followed by a clinical and cytogenetic evaluation [8,11,18].

Studies reported by UNSCEAR [19] describe that more than 80% of computed tomography and general radiography technicians have no measurable exposure. On the other hand, the individual effective dose average of interventional procedures is significantly higher than of the diagnostic area. As verified, interventional physicians belong to the HCW most exposed to X-rays in the hospital environment, corroborating the studies reported by UNSCEAR [15,19]. For this reason, it is important to evaluate the data of physical dosimetry in a separate hospital environment in diagnostic radiology and interventional radiology, since a joint descriptive estimate may mask significant differences [15,19]. In the present study, doses above the recording level are distributed in 41.64% of workers, an expressive number of professionals who, due to their occupational routines in controlled areas, are exposed to

X-rays at significant levels for one or more months, highlighting the importance of effective physical dosimetry as a health surveillance tool [8,11,17,18].

The evaluation regarding the CBC tests (leukocyte and platelet count) was performed in 645 workers, since not all the participants performed CBC tests for analysis in the hospital's laboratory during the research period. Only 200 CBC tests showed some deviation from the normality reference adopted by the clinical analysis laboratory [12]. Leukopenia and thrombocytopenia were identified in only 1.09% (95% CI, 0.84 - 1.39) of CBC tests for leukocyte count and 2.13% (95% CI, 1.78 - 2.53) for platelet count. Association of abnormal immunological responses to accumulated exposure in low doses has no significance as stated in the studies by Forslund et al. [21], Gelas et al. [22], Zare et al. [5] and Orji et al. [23]. Currently it still has dissociated confounding factors [1,2,19], such as cigarette smoking and stress [24-27].

The dose threshold for hematopoietic depression of Acute Radiation Syndrome, a deterministic effect of radiation, requires equivalent doses of the whole body higher than 800 mSv [8,13], that is, 800 times higher than the regulated investigation level or 40 times the annual dose limit, which would be unacceptable for the worker's safety. There are no records of events reporting this level of exposure and relationship when applying X-rays in a hospital environment, whether accidental or occupational. In the systematized review, a single case report was identified by Elmiger et al. [29] when an acute exposure event of a maintenance technician working on angiography equipment, accidentally received an estimated effective dose of 5 mSv, being 200 mSv on the skin, 100 mSv on the eyes and 700 mSv on the extremity (hand). This worker presented erythema on the hand and face, but the dose estimate did not reach the limits for deterministic effect, not characterizing relational causality. [29]

Thus, the present study corroborates what was reported by different authors [5,10,13,23] and national and international organizations [6,8] as it does not identify a statistically significant relationship between the leukocyte and platelet counts of CBC tests and the radiation dose levels of HCW in diagnostic and interventional radiology.

As limitations of the research, we can report the restriction as to the access, as well as the record of the results of the CBC tests carried out in laboratories outside the hospital, as well as the inclusion in the evaluation of the counts of the whole leukocyte formula. As for physical dosimetry, the study did not consider the audit of the use of personal dosimeters or PPE by workers and aspects of individual dose estimation through monitoring of the workplace. [8] The PPE attenuation was not considered for personal effective dose estimation. On the other hand, weighting for the equivalent dose to the skin, hands, feet or lens of the eye was not considered. Workers wear a single dosimeter on their lead apron, at chest level, making these estimates unfeasible. To define the effective dose, the simplified form guided by ICRP for external radiation exposure was used: "the personal dosimeter used on a position of the body representative of its exposure, provides an effective dose value sufficiently accurate for radiological protection purposes". [17]

Although the CBC test is not listed as an effective biomarker for biological effects due to low radiation values delivered to HCW, it does not mean that there is no biological effect. Continuity of studies to define the best biomarkers for occupational health risk management of workers exposed to radiation in the healthcare environment must be continued. In fact, biological effects have already been reported in interventional radiology workers, such as damage to the lens of the eye [8,16,17], indicating that we must be careful in this regard.

4. CONCLUSIONS

The findings of the present study demonstrated that there was no statistically significant relationship between the individual effective dose and the leukocyte and platelet count in the CBC tests in all analyses performed on healthcare workers exposed to X-rays in a university hospital. The simple counting of elements in the blood has not been characterized as a suitable biomarker for low dose X-ray exposure. Even leukocytes, one of the most sensitive components of blood, did not show a significant response to radiation at ordinary occupational levels.

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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