Biological effects of Body Scanner equipment

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Resumo: Para que ocorra uma eficácia melhor nos planos de radioproteção de equipamentos body scanner, torna-se necessário que a biologia por trás desses aparelhos seja estudada, de modo que os efeitos biológicos sejam vistos de uma forma nunca vista anteriormente. Dessa forma, o artigo indicou que os sistemas body scanner não apresentam riscos significativos em uma única exposição devido sua baixa dose, menos de 100 µSv. Entretanto cabe investigar os efeitos dessa exposição integrada a trabalhadores que necessitam se submeter a estes equipamentos em sua rotina.

Palavras-chave: Espectro de Raios X, Biologia, Radiobiologia, Body Scanner

Abstract: For account the best efficacy in radioprotection plans of body scanner equipment, it is necessary that biology behind the apparatus, so that biological effects be seen in a form never seen before. Thus, the article indicated that body scanner systems do not present significant risks in a single exposal due to their low dose, less than 100 µSv. However, it is worth investigating the effects of integrated exposure to workers that need to undergo this equipment in their routine.

Keywords: X-Ray Spectrum, Biology; Radiobiology; Body Scanner

1. INTRODUCTION

In 1927 an experiment made by Mueller, a Texas University zoologist of, using Drosophilas prove that it is noticeable that after radiating the parental lineage the damage caused to the subsequent strains will be linearly proportional to the amount of dose used. In that sense, it was also noticed an increase in the rates of mutations and chromosomal rearrangement after the use of ionizing radiation.

The biological effects of ionizing radiation can be classified as somatic (effects on irradiated individuals) or germinative (on the offspring of irradiated individuals), and biomolecules can be damaged by two mechanisms: direct and indirect (Freitas et al., 1998). The direct mechanisms are derived from the interaction of radiation with DNA and RNA molecules resulting in mutations, cell death, carcinomas, and genetic abnormalities. The indirect mechanisms occur due to the interaction of radiation with water or oxygen molecules resulting in the formation of ion pairs, reactive oxygen metabolites, such as hydrogen peroxide and hydroxyl radicals (Smith, 1988 apud Abbott, 2000; Whitmyer et al., 1997; Freitas et al., 1998).

2. PHOTON INTERACTION WITH MATTER

Image formation in Body Scanner equipment is due to the interaction of photons with biological matter, this will undergo variation according to the composition and the irradiated material, due to the different types of tissues present in the human body. There is variance in the level of radiation absorption in each of them (a bone tissue does not receive the same amount for example as an epithelial tissue).

Some factors contribute to the increase in dose absorption, such as increased tension and increased current for the production of sounds, and also the prolongation of exposure time. These practices are applied when an image with more intense intensity (Curry III et al., 1990).

The photons in the energy range of interest to this work may undergo three processes. The main process, and also the most important to detection and dose deposition is the photoelectric effect. In this process, there are, in most cases, the full energy deposition in the medium. On the other hand, the Compton Scattering represents a partial energy deposition in the medium, making the photon change its direction, energy and also ejecting an electron from the atom. The third process is the Rayleigh scattering where the photon changes its direction without losing energy (Gilmore, 2008).

3. IONIZING RADIATION AND ITS EFFECTS ON PREGNANCY

Due to the fetal vulnerability that is found mainly during the first days after the karyogamy process and later result in the formation of the still in the first week of the morula and blastula the lack of cellular differentiation of the blastomeres that are in the state of totipotency can lead to a prenatal death and being later than that period when the zygote is in the gastrula, neurula and subsequently, and may result in fetal malformation in doses of 1Gy or more.

Doll (1998) found that doses below 0.1Gy received by women during pregnancy are not able to induce leukemia in children, a fact confirmed by longitudinal observations in irradiated fetuses. However, despite having a low risk of leukemia induction when using low doses of radiation, this risk should not be overlooked (Abbott, 2000).

Some effects of ionizing radiation can be observed, for example: genetic damage that leads to disease in the subsequent offspring, damage to the fetus, the production of cancer in the individual irradiated system and the production of another disease or, as originally suggested, nonspecific aging (Doll, SR 1998).

The only effect that has been clearly demonstrated is mental retardation occurring with exposure for 8–25 weeks intrauterine life with severe delay quite common for doses of 1 Gy or more, less common with doses of 0.5 to 1 Gy, and did not cause evidently in lower doses. (Doll, S. R. 1998).

The only other effects seen were small reductions in IQ, a reduction in size, and seizures. The most recent analyzes provide no reason to think that small heads were caused after the 15th week of pregnancy (Doll, S. R. 1998).

It is worth remembering that the ionizing radiation from Body Scanner equipment ranges from 0.2 µSv to 4 µSv in the equipment found on the market, equivalent to 2 x 10-7 Gy and 4 x 10 -6 Gy respectively, a much lower dose than those mentioned above. If converted to the hypothetical value of 0.4 Gy (value chosen because it is below 0.5 and obviously does not cause gestational problems) it is equivalent to 400000 µSv, a dose higher than that observed in the Body Scanners.

Before that period, two-fifths were associated with mental retardation and three fifths with generalized growth impairment, which, unlike mental retardation, was caused only in weeks 1 to 7 (Otake and Schull 1993).

Seizures aged 2 years or more were related to dosing only when the child was exposed at the post-ovulatory age of 8 to 15 weeks. This is not associated with severe mental retardation or some strange cause was related to the dose in an apparently linear manner, with no statistical reason to postulate a threshold (Dunn et al 1990)

Table 1: Quantitative risks of fetal brain damage by irradiation at post-ovulatory age 8 to 15 weeks (after UNSCEAR 1993) Doll, S. R. 1998)

Damage	Risk† from exposure to 1 Gy
Serious mental retardation	Increased from 0.8% to 40%
IQ	Loss of 25–30 percentage points
School performance	50th percentile reduced to 10th percentile
Unprovoked seizure in absence of serious mental retardation	Increased 25 times at ages 2 years and over

4. CELLULAR RADIOSENSITIVITY

It is of utmost importance to highlight the factors that may or may not affect cellular sensitivity in the face of exposure to ionizing radiation that changes according to cellular standards. Cellular radiosensitivity will vary according to the factors to be discussed below.

4.1 Proliferative State

That is, when the cells are with the high mitotic capacity they become more sensitive to ionizing radiation.

4.2 Specialization Degree

Cells can be termed totipotent (capable of differentiating into any tissue in which the organism is composed, including even extra-embryonic tissues), pluripotent or multipotent (capable of differentiating into any of the three embryonic leaflets called mesoderm, endoderm, and ectoderm, however, they cannot create extra-embryonic tissue such as placenta and embryonic attachments), oligopotent (differentiate within a single lineage, being able to differentiate in a few tissues) and omnipotent (cells differentiated into a single cell type). Depending on its specialization degree, variance in radiosensitivity will occur, in which the less specialized the cell, the greater its radiosensitivity;

4.3 Moment in the Cell Cycle

The moment in the cell cycle process is also an important factor, the G1 and S moments become more resistant than the cells that are in the process of mitosis or in the G2 phase.

In addition, it is worth mentioning that chromosomal compaction becomes a very important factor when it comes to repairing damaged genetic material, which may highlight single or double break of the ribbon, and repairs to the nitrogenous bases, of a nucleotide in all or a sequence nucleotide. The greater the compaction, the less access will be made to the damaged DNA molecule, thus making it more difficult to repair through active enzymatic processes. It is worth remembering that in the cell cycle mitosis phase, mainly in the phases of prophase, metaphase and anaphase are the moments in which chromosomal compaction is found, mainly in the metaphase phase in which they reach their maximum degree of compaction, making the DNA inaccessible thus reducing the production of proteins, absence of nucleolus and also with that the production of mRNA rarely occurs, in cases that do not change polarization. Its compaction is also denoted in the G1 phase, as the DNA must be compacted for the duplication process. This process occurs due to the presence of several novel proteins such as histones, and it is precisely for this reason that it presents the absence of a good part of the enzymatic processes. However, there are enzymes capable of changing the polarity of some DNA sequences making that region stay accessible for other enzymes. This becomes necessary for cell duplication to occur, but it prevents access to DNA sequences, nitrogenous bases, and nucleotides due to physical factors.

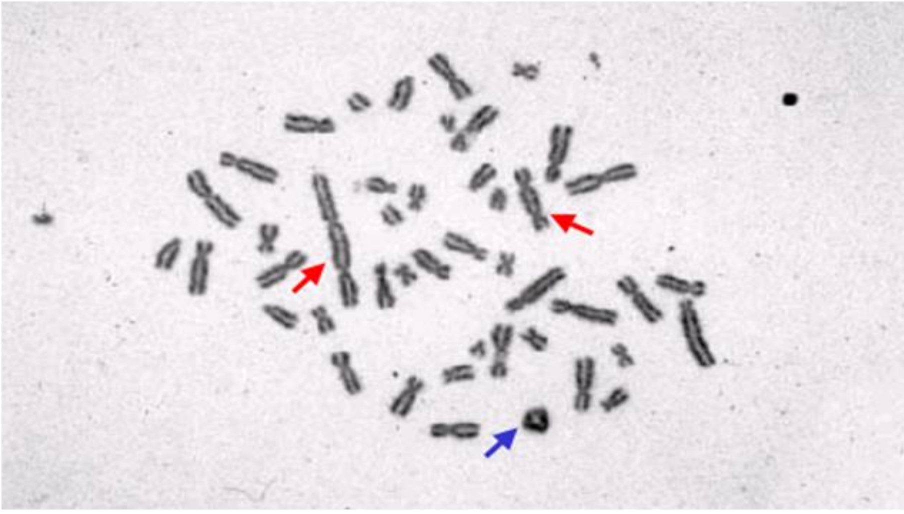

Figure 1: Metaphase of an individual exposed to ionizing radiation, showing two dicentric chromosomes (red arrow) and one ring (blue arrow) (IAEA, 2001) (Fernandes, 2005)

5. TISSUES RADIOSENSITIVITY

As the radiation penetrates the tissues, it loses energy through a series of random collisions and interactions with the atoms and molecules that cross the path, these collisions originate ions (electrons pulled from the electrosphere).

Among the tissues that are more sensitive to ionizing radiation, hematopoietic tissues and reproductive cells, young bone and epithelium of the digestive tract, skin, and muscle, and nervous tissue, respectively, can be highlighted in terms of sensitivity.

It is worth remembering that the greater the specialization of these cells, the lower the probability of death due to radiation incidence, thus being both factors inversely proportional.

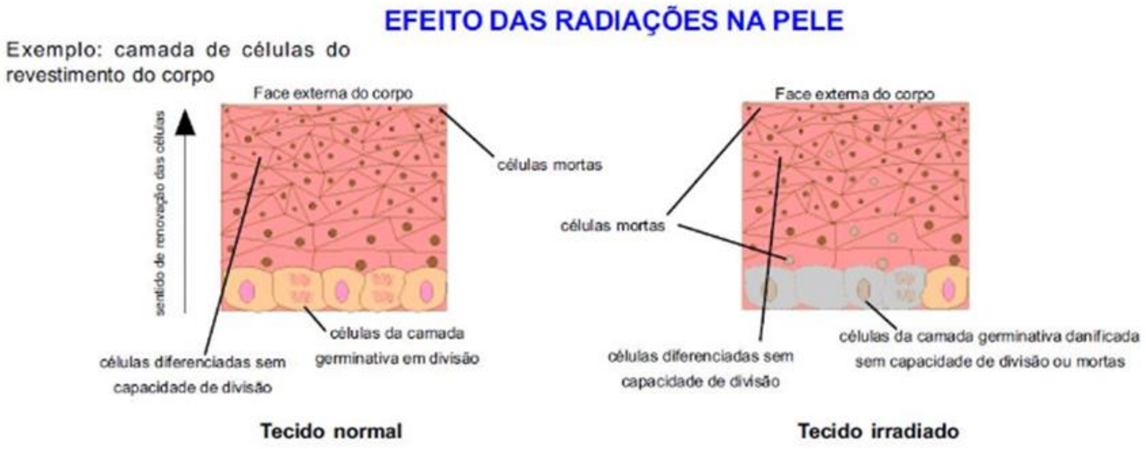

Figure 2: In figure 2, there is epithelial tissue. First a normal tissue, second an irradiated epithelial tissue, it is possible to see germinative cells damaged or dead because of de radiation.

A tissue may have greater or lesser resistance to radiation, depending on the degree of differentiation of the cells that constitute it. (Bardini, C. G. 2017)

6. BODY SCANNER SPECTROMETRY

The formation of an X-ray spectrum occurs due to several factors, such as the presence of attenuating materials and also the amount of energy used. Unlike mammography or computed tomography systems, Body Scanner systems use a voltage that can be varied between 150 kV and 160kV, with filtration values that can range from 3.9 mm of aluminum and tungsten anode to 6.8 mm of Al + 1mm of Al. The variation in μA of the operating values in 160kV can vary in values from 850 μA up to 1000 μA, which will vary according to the equipment manufacturer (Bastos, C.O. 2019).

In that sense, were made an experimental investigation of the X-ray beam in the 160 kV voltage in the tube model MXR-160/22 da COMET, with 0.8 mm of Be intrinsic filtration. To accomplish this proposal it was used a compact spectrometry system from Amptek. This system is composed by an XR-100T CdTe spectrometer, that comprehends the preamplifier and the detector and also a PX5 digital pulse processor that comprehends the amplifier and the multichannel analyzer.

So, within this apparatus were made some measurements varying the additional filtration from 0 mm to 7.8 mm of Al at 160 kV voltage and 0.1 mA anodic current for 4 min. Because of the high photon fluence, it was used a 1 mm thick tungsten collimator with a 400 μm pinhole to avoid big distortions by a signal pile-up and dead time. In that way, in the figure, there are the nine spectra obtained.

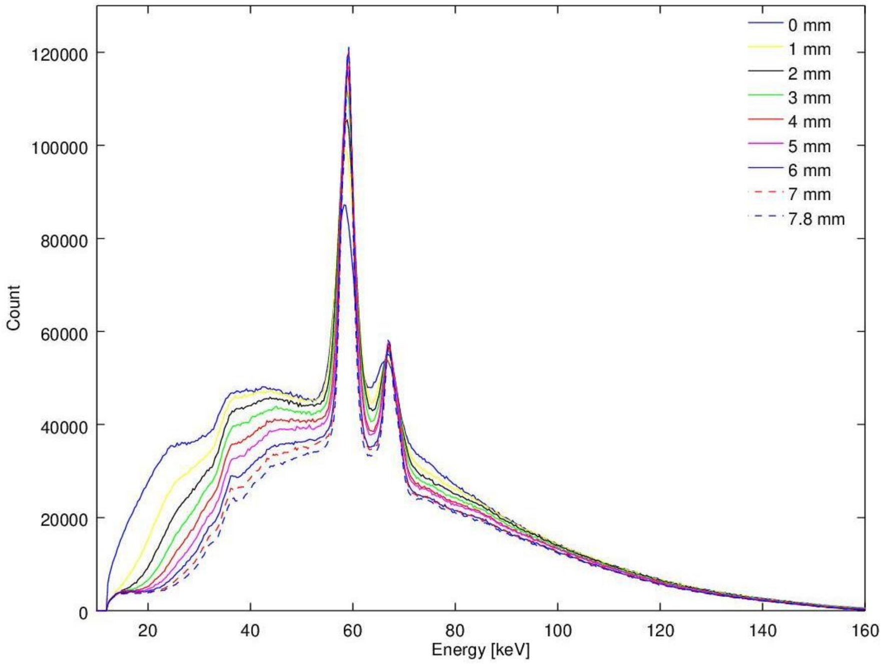

Figure 3:Spectra obtained varying the Al filtration in a fixed 160 kV voltage.

As could be seen in figure 3, there are two peaks between 55-70 keV. They are representative of the 59,31 keV k_α and 67,23 keV k_β characteristic X-ray from the tungsten anode. In that sense, those peaks could be classified as a standard behavior of body scan equipment to obtain an image.

Is also worth mentioning that when increasing the additional filtration, higher is the probability of the photon be absorbed in the filtration. This fact can be seen in figure 3 where the low energy photons are attenuated with the increase in the filtration, decreasing the final dose. In that sense, in figure 4 there is the 6.8 mm + 1 mm of Al filtration. This shows an enhanced spectrum due to its high aluminum filtration removing low energy photons that only contribute to patient dose.

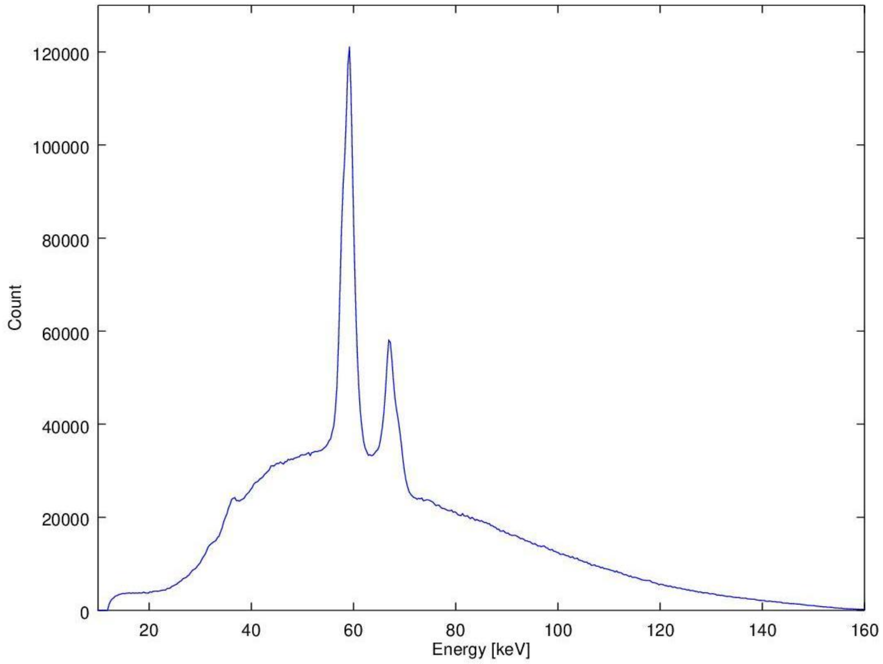

Figure 4: X-ray spectrum at 160 kV voltage with 6.8 mm + 1 mm of Al filtration.

7.CONCLUSION

It is noted that despite the tissue, cellular and fetal radiosensitivity, the body scanner does not present significant risks in a single exposal due to the low dose of its radiation, less than 0.00001 Gy (= 100 μSv). However, it is worth investigating if the integrated dose in a worker that needs to undergo to an exposure every day because of his job is also negligible.

In addition, as observed in figure 3 and figure 4, the greater the additional filtration the greater is the attenuation of low-energy photons that would bring to the user a higher dose without any benefit for image production. In that sense, is reasonable to use higher filtrations as a matter of optimizing the dose.

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REFERENCES

Nunes, F. L. S. “Introdução ao Processamento de Imagens Médicas para Auxílio ao Diagnóstico – Uma Visão Prática”

OKAZAKI, K. (fevereiro de 1995) “EFEITOS DA RADIAÇÃO IONIZANTE EM CÉLULAS NOÇÕES BÁSICAS” disponível em <http://repositorio.ipen.br/bitstream/handle/123456789/24705/05653.pdf?sequence=1>

Bardini, C. G. (2017) “BIOFÍSICA DAS RADIAÇÕES IONIZANTES” disponível em < https://docplayer.com.br/15620707-Biofisica-das-radiacoes-ionizantes.html>

Doll, R. (s.d.). Effects of small doses of ionising radiation. Fonte: IOPscience: http://iopscience.iop.org/0952-4746/18/3/003

Gilmore, G. (2008). *Practical Gamma-ray Spectroscopy*. John Wiley & Sons.

Risco de Indução ao Câncer associados ao uso de Escâneres Corporais de Raios X por Transmissão em Aeroportos. In: RADIO 2011, 2011, Recife. Proceedings of RADIO 2011. São Paulo: ABENDI, SBPR e SPPCR, 2011.

BASTOS, C. O.; BUENO, L. O. ; PEIXOTO, J. G. P. . Radioproteção dos equipamentos Body Scanner instalados em locais públicos. In: Congresso Brasileiro de Metrologia das Radiações Ionizantes, 2018, Rio de Janeiro. Radioproteção dos equipamentos Body Scanner instalados em locais públicos, 2018.

Kuhna, P. & Huhn, A., 2017. Importância da habilitação profissional para operadores de escâneres corporais em presídios, Santa Catarina.

Samanda Cristine Arruda Correa, Josilto Oliveira de Aquino, Edmilson Monteiro de Souza, Ademir Xavier da Silva, Avaliação da Dose e do Risco de Indução ao Câncer associados ao uso de Escâneres Corporais de Raios X por Transmissão em Aeroportos, visitado em julho de 2019

ICRP, 2007. Recommendations of the International Commission on Radiological Protection ICRP publication 103,

ICRP, 1990. Recommendations of the International Commission on Radiological Protection ICRP Publication 60,

Lima, A.R. & Gomes, A.S., 2013. Tecnologia de scanner corporal por raios-X. Available at:

http://aproterj.com.br/noticias/214-tecnologiade- escaner- corporal-por- raios-x>

OKUNO, E.; YOSHIMURA, E. M. Física das radiações. São Paulo: Oficina de Textos, 2010

Peixoto, J.G.P. et al., 2016. Ionizing Radiation Metrology 1st ed. J. G. G. Peixoto, ed., Rio de Janeiro, Brazil.

Scaff, L.A.M., 1979. Bases físicas da radiologia – diagnóstico e terapia Sarvier., São Paulo.

ICRP, 2007. Recommendations of the International Commission on Radiological Protection ICRP publication 103,

ICRP, 1990. Recommendations of the International Commission on Radiological Protection

HUFFMAN, Chad; ERICSON, Lars. Body Cavity Screening for Criminal Justice: Market Survey. DOJ Office of Justice Programs National Institute of Justice Sensor, Surveillance, and Biometric Technologies (SSBT) Center of Excellence (CoE). April 24, 2014.

Fernandes, T. d. (FEVEREIRO de 2005). EMPREGO DAS ABERRAÇÕES CROMOSSÔMICAS INSTÁVEIS E MICRONÚCLEOS NO BIOMONITORAMENTO INDIVIDUAL: ESTUDO COMPARATIVO. Fonte: Universidade Federal do Pernambuco: https://repositorio.ufpe.br/bitstream/123456789/9930/1/arquivo9082_1.pdf

BASTOS, C. O.; PEIXOTO, J. G. P. . FORMAÇÃO DA IMAGEM EM EQUIPAMENTOS BODY SCANNER. In: Congresso Brasileiro de Metrologia das Radiações Ionizantes, 2019, Florianópolis. FORMAÇÃO DA IMAGEM EM EQUIPAMENTOS BODY SCANNER, 2019.