EVALUATION OF BISMUTH SHIELDING EFFECTIVENESS IN REDUCING BREAST ABSORBED DOSE DURING THORACIC CT SCAN

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Abstract

Computed Tomography (CT) is an essential method for tracking neoplasia's and efficiently diagnosing a wide variety of thoracic diseases. CT is generally considered the most accurate choice for lung examination. Due to the growing use of CT, breast and other superficial and radiosensitive organs are unnecessarily irradiated during radiological procedures, thus requiring the development of strategies appropriate to optimize and, if possible, to reduce the radiation dose. The use of bismuth shielding to reduce radiation dose absorbed by breast during thoracic CT examinations has been the subject of many studies recently published by Brazilian and foreign authors of various fields. The purpose of this paper is both to accurately determine the glandular dose when breast is exposed to radiation and to assess the reduction in absorbed dose during thoracic CT examinations, using a set of Thermoluminescent Dosimeters (TLDs), an anthropomorphic phantom and bismuth shielding.

***Keywords*:** Thoracic CT scan, Breast absorbed dose in CT, Bismuth shielding in CT.

1. - INTRODUCTION

Since the introduction of Computed Tomography (CT) in 1972, the use of radiological examination as a method of diagnosis increased steadily. Concurrently, concern about doses absorbed by patients is increasing because of the availability of Multi-detector Computed Tomography (MDCT), which favors faster images at higher doses. Regarding thoracic Computed Tomography, Mannudeep et al. [2004] stated that this is an essential examination to track neoplasias and to efficiently diagnose a wide variety of thoracic diseases, in addition to being the most accurate technique for lung examinations. Due to the growing use of CT, the breast and other superficial and radiosensitive organs are unnecessarily irradiated during radiological procedures, thus requiring the development of strategies appropriate to optimize and, if possible, to reduce the corresponding radiation doses. The optimization of radiation doses is a crucial question: the benefits of an accurate diagnosis have to be balanced against the risk of radiation, always keeping in mind the ALARA Principle. When subject to Computed Tomography, patients receive relatively high doses, and the increasing demand for CT had a considerable impact on doses taken by patients and on the exposure of the population as whole, according to Goldman Lee [2007]. No scientific study has detected a direct connection between cancer and CT radiation, as stated by Yilmaz [2007]. However the growing exposure of radiosensitive organs, such as the breast and the thyroid, is reason for serious concern. Low CT doses, substantially reducing the tube current, are being recommended to detect lung nodules. Low doses in high-resolution thoracic CT provide results equivalent to those obtained with higher standard radiation doses [Michel *et al*., 2001].

The use of bismuth shielding to reduce the dose absorbed by breast during thoracic CT examinations was addressed in relevant studies and published papers. Several researchers are studying methods to reduce doses absorbed by patients during CT examinations: Hooper et al. [1997], for instance, evaluated breast, eye and testicle doses using bismuth shielding in thoracic CT examinations and observed 57%, 40% and 51% average reductions, respectively. Yilmaz et al. [2007] evaluated superficial breast doses in 50 women submitted to thoracic CT and observed a 40.53%-reduction of the doses. The same study, carried out using a phantom, yielded a 17.33%-reduction of the dose. Hulten et al. [2013] have analyzed image quality using bismuth shielding in Coronary Computed Tomography Angiography (CCTA) and suggested further research. Wang et al. [2011] studied dose reduction and image quality taking into account bismuth shielding and changes to CT's tube current. Einstein et al. [2012] documented the additional protection from radiation provided by bismuth shielding of the breast, which reduces doses absorbed by the breast and adjacent organs, but warned that the impact on image quality must be studied. McCollough et al. [2012] clearly explained the disadvantage in using bismuth shielding as a technique to reduce doses in CT examinations. The major objective of our study is to investigate the change in absorbed doses brought about by bismuth shielding the breast in lung examinations using thoracic tomography.

2. - MATERIALS AND METHODS

Doses were measured using an Alderson Rando® anthropomorphic phantom equipped with Thermoluminescent Dosimeters (TLDs). The anthropomorphic simulator consists of a human skeleton wrapped in rubbery material. In its feminine version, the phantom approximately simulates a 1.55 meter-high woman, weighing 50 kg. Trunk and head are sliced in thirty-one 2.5 cm-thick pieces. Each slice contains uniformly placed cylinders, 7 mm in diameter, where a total of 4049 thermoluminescent dosimeters are installed. Figure 1 shows the phantom's position at the CT unit's isocenter. TLDs were positioned at the phantom's lungs, thyroid and breast, to measure the doses absorbed by these organs.

Figure 1. Female Rando Alderson phantom during positioning in the CT unit.

The phantom was digitized according to the clinical protocol defined for thoracic computed tomography that employs 16 MDCT scanners (GE Healthcare, BrightSpeed 16 Select). A preliminary assessment (scout) was carried out to check the positioning of materials and to delimitate the area to be irradiated.

Two thoracic CT scans were conducted according to the following set of parameters: tube voltage: 120 kV; tube current: 150 mA; step 1; beam thickness: 7 mm and distance: 170 mm. For the first scan, 3 (three) thermoluminescent dosimeters (TLDs) were inserted in the phantom's neck, close to the thyroid gland, 3 (three) TLDs were inserted in each breast (left and right) and 3 (three) TLDs were inserted in the area of the right and left lungs. For the second MDCT scan, the thyroid, breast and lung TLDs were replaced by another set of dosimeters, and bismuth shielding (*Attenurad System Shield*; F & L Medicos products, Vandergrift, PA) was positioned on the breast.

The shielding positioned on the breast consists of a1 mm-thick piece of bismuth embedded on rubbery foil. Figure 2 shows examples of the images obtained. The TLDs were sent for reading on the following day after irradiation.

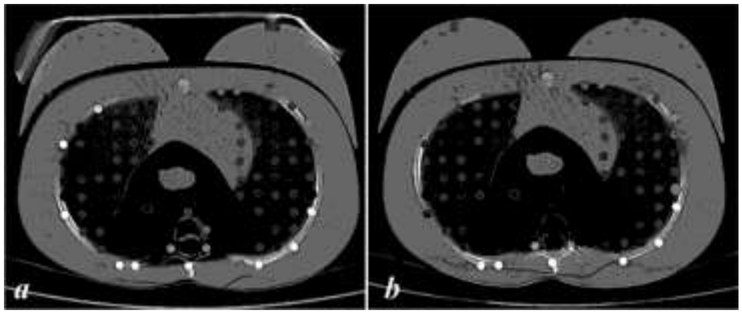

Figure 2 - Axial thoracic CT images: (a) with and (b) without bismuth shielding.

Harshaw LiF:Mg,Ti TL100 rod (Diameter: 1 x 6 mm) thermoluminescent dosimeters (5% fading in one year at 25˚C; 10^{-4} to 10^{0} Gy linearity in ^{60}Co; 10^{3} Gy utilization limit and $5x10^{3}$ Gy saturation) were read on a Model 4500 Harshaw/Bicron Reader, manufactured by Thermo Electron Corporation. Thermal treatment: 400ºC for 1 hour and 100ºC for two hours. Treatment prior to reading: 100ºC for 10 minutes in automatic oven. Signals emitted by TL dosimeters during heating from 50ºC to 260ºC were also read with a Harshaw Reader, at a rate of 10 ºC.s^{-1}.

The metrological reliability of the TLDs was demonstrated by means of homogeneity and reproducibility tests and by calibration at a specific CT reference radiation (RQT9) [IEC, 1997], reproduced at the Dosimeter Calibration Laboratory of the Nuclear Technology Development Center - CDTN/CNEN. The set of preselected dosimeters used exhibited a reproducibility of 7.5% and 20% homogeneity; they were calibrated, in terms of absorbed dose to air, in a ^{137}Cs gamma beam in electronic equilibrium conditions. The calibration coefficient was 85.39 μGy nC^{-1} for the whole batch of dosimeters.

Organ absorbed doses were evaluated using TL-100 dosimeters inserted in the anthropomorphic simulator Alderson Rando® Feminine during thoracic CT scans. The dose absorbed by each organ (D_T) was evaluated by reading TLDs' accumulated doses (in nC) and multiplying readings by the calibration coefficient of the TLDs (in µGy/nC), as obtained at the dosimeters calibration laboratory.

3. - RESULTS

Organ absorbed doses determined with TLDs are shown in Table 1and Figure 3. The highest recorded dose occurred in the thyroid (24.3 mGy) and in the lung (12.5 mGy) since they were in the incidence region of the x-ray primary beam, without bismuth protection. The recorded organ doses in two scans, with and without bismuth shielding, showed significant differences. The comparison between scans indicated that the largest dose reduction, which occurred in the thyroid, was approximately 50%and was a consequence of reducing the scattered radiation. Dose reduction in breast was approximately 30%.

Table 1 - Maximum variation of absorbed dose in some organs during thoracic CT scans with and without bismuth shielding on breast

Organ	Organ absorbed dose - Maximum variation		
	Without bismuth shielding (mGy)	**With bismuth shielding (mGy)**	**Dose Reduction (%)**
Right lung	11.5	6.2	46.09
Left lung	12.5	6.4	48.80
Thyroid	24.3	12.2	49.79
Right breast	8.3	5.8	30.12
Left breast	8.2	5.7	30.49

Most articles addressing the influence of bismuth shielding on dose reduction found by the authors in the specialized literature and related to thoracic CT scans for lung examination were conducted on the surface of organs. Our study, differently, analyzed the change in the glandular dose during exposure of the breast. According to Hopper et al. [1997], the average radiation dose reaching the breast during thoracic CT is 22 mGy. They calculated the superficial breast dose, that is, the radiation dose measured at the surface, which is obviously higher than the actual glandular dose of 5.8 mGy.

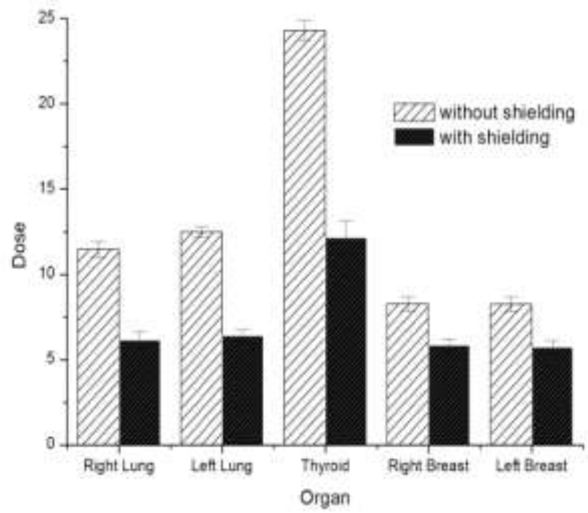

Figure 3 – Influence of bismuth shielding on absorbed doses for some organs

4. - DISCUSSION

Unnecessary exposure to radiation may result from the use of high doses, far from ideal, to produce higher resolution images. On the other hand, at low doses, the image quality may be poor and interfere with clinical diagnoses. Breast shielding degrades image quality and increases noise. In case the increase in noise is still acceptable for diagnosis, as argued by the advocates of this method, it would be better to reduce the tube current, instead [McCollough *et al*., 2012].

According to Robert Gould, despite the disadvantages, the use of bismuth shielding is simple and efficient at reducing the breast-absorbed dose. A significant disadvantage results from the combined use of bismuth shielding and automatic exposure control systems, as in some CT Scanners, which excessively increases doses to the detriment of image quality [McCollough *et al*., 2012].

This paper does not study the effect of bismuth shielding from the viewpoint of image quality and no measurement was conducted varying the tube current.

5. - CONCLUSIONS

Organ absorbed doses were determined during thoracic CT scans with and without bismuth shielding on breasts. Dose values have been significantly reduced; the readings suggest that the use of bismuth would be a proper procedure for optimization. However, the influence of bismuth on the image quality requires study.

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