Applied Radiation and Isotopes 117 (2016) 55–57

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Assessment of breast absorbed doses during thoracic computed tomography scan to evaluate the effectiveness of bismuth shielding

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HIGHLIGHTS

- Organ dose reduction in CT examinations is a concern to minimize radiation risks.
- Some organs are unnecessarily exposed to radiation during CT scans.
- Reduction of absorbed dose in breasts and nearby organs during thoracic CT with bismuth shielding was studied.
- Bismuth shielding proved to be a simple procedure to reduce significantly the absorbed dose in organs.
- The influence of the bismuth shielding on the CT image quality should be taken into account.

ARTICLE INFO

Article history:
Received 29 October 2015
Received in revised form
16 March 2016
Accepted 16 March 2016
Available online 19 March 2016

Keywords:
Thoracic CT scan
Breast and nearby organ absorbed dose in CT
Bismuth shielding

ABSTRACT

During a lung computed tomography (CT) examination, breast and nearby radiosensitive organs are unnecessarily irradiated because they are in the path of the primary beam. The purpose of this paper is to determine the absorbed dose in breast and nearby organs for unshielded and shielded exposures with bismuth. The experiment was done with a female anthropomorphic phantom undergoing a typical thoracic CT scan, with TLD-100 thermoluminescent detectors insert at breast, lung and thyroid positions. Results showed that dose reduction due to bismuth shielding was approximately 30% and 50% for breast and thyroid, respectively; however, the influence of the bismuth on the image quality needs to be considered.

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1. Introduction

The use of radiological examinations as a method of diagnosis has steadily increased; thoracic CT became an essential radiological examination to track neoplasia and to diagnose a wide variety of thoracic diseases; it turned out the most accurate technique for lung examinations (Kalra et al., 2004).

The increasing demand for CT had a considerable impact on doses provided to patients and on the exposure of the population as whole (Goldman, 2007). The concern on radiation risks for patients has also increased mainly when multi-detector computed tomography (MDCT) is used, since it allows obtaining fast images, however by providing high doses to the patient relatively to other techniques. No scientific study has detected a direct connection between cancer and CT radiation, as stated by Yilmaz et al. (2007). However, the growing unnecessarily exposure of breast and nearby radiosensitive is reason for serious concern. The development of proper strategies to optimize and, if possible, to reduce the radiation doses imparted to those organs is required; for instance, a low dose CT procedure to detect lung nodules is recommended by reducing the x-ray tube current (Michel et al., 2001). The optimization of radiation exposures is a crucial question: benefits of a good quality image for a precise diagnosis have to be balanced against the risk of radiation.

The use of bismuth shielding during thoracic CT examinations to reduce the absorbed dose in breast and nearby organs was addressed in relevant studies. For instance, Hopper (2002) observed 57%, 40% and 51% dose reductions in breast, eye and testicle, respectively; Yilmaz et al. (2007) found the reduction up to 53% in the breast superficial dose in 50 women; Hulten et al. (2013) analyzed the influence of the bismuth shielding on the image quality and suggested further research; Wang et al. (2011) compared dose reductions and image quality for bismuth

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http://dx.doi.org/10.1016/j.apradiso.2016.03.018
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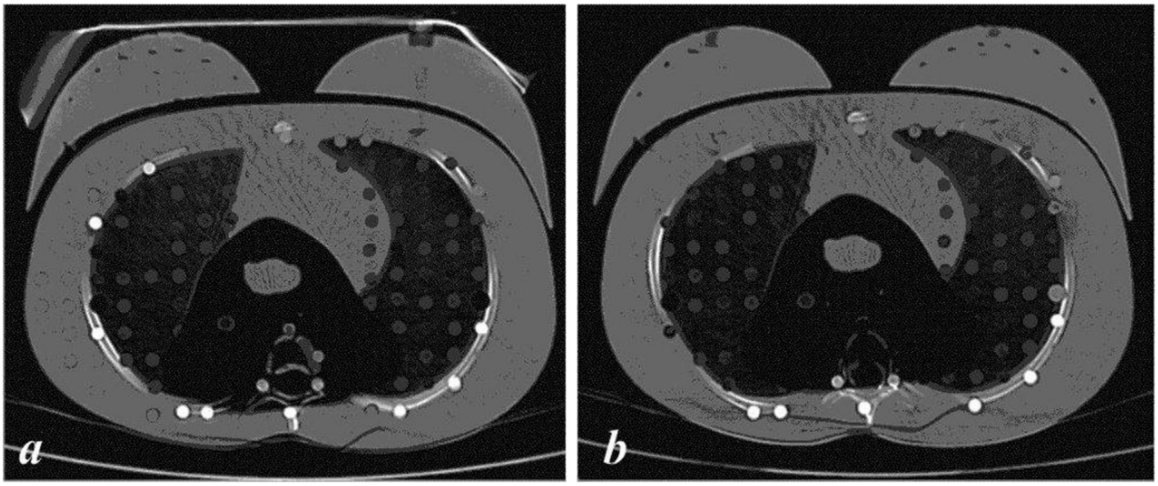

Fig. 2. Axial thoracic CT images: (a) with and (b) without bismuth shielding over the breasts of the phantom.

shielding and changes in the x-ray tube current; Einstein et al. (2012) showed to be in favor of breast bismuth shielding but McCollough et al. (2012) were clearly against.

The main objective of this study was to investigate the change in absorbed doses in breast due to shielding with bismuth during lung examinations with thoracic computed tomography.

2. Materials and methods

An Alderson Rando® female anthropomorphic phantom was positioned at the isocenter of a BrightSpeed 16 Select GE Healthcare CT unit; a preliminary scout was carried out to verify the phantom positioning and to delimitate the area to be scanned. The phantom was scanned according to the clinical protocol defined for thoracic CT that employs 16 MDCT scanners: 120 kV, 150 mA and 7 mm beam thickness. Fig. 1 shows the phantom's position in the CT unit and Fig. 2 shows the axial thoracic CT images with and without a 1 mm thick piece of bismuth embedded in a rubbery foil over the breasts.

Harshaw rod shape LiF:Mg,Ti TL100 thermoluminescent (TL) dosimeters were used for absorbed dose measurements. The annealing cycle of the TL dosimeters was 400 °C for one hour followed by 100 °C for two hours before radiation exposure and 100 °C for 10 min. before reading. Readout of the TL dosimeters was done in a 4500 model Harshaw/Bicron Thermo Electron Corporation TL reader during the temperature range of 50 °C up to 260 °C with a temperature rate of 10 °C.s^{-1} (Harshaw, 2001).

Fig. 1. Alderson Rando® female anthropomorphic phantom positioned in the CT unit for absorbed dose measurements.

The metrological reliability of the TL dosimeters was assured by selecting a set with 7.5% reproducibility and 20% homogeneity and by calibrating them in a RQT 9 IEC reference quality at the Dosimeter Calibration Laboratory (IEC, 2005). The calibration coefficient in terms of absorbed dose in air of the preselect set of TL dosimeters was 85.39 µGy nC^{-1}.

As this study aimed to verify the dose reduction due to the bismuth shielding, TL dosimeters were inserted around a specific point in the phantom at the corresponding position of the right and left lungs, thyroid and breasts.

3. Results

Absorbed doses in the organ positions in the phantom are shown in Table 1 and Fig. 3. The highest recorded dose of 24.3 mGy occurred in the thyroid position that stressed the situation of unnecessary radiation exposure. The recorded doses due to scans with and without bismuth shielding showed significant differences; the largest dose reduction of 50% occurred in the thyroid was a consequence of reducing the scattered radiation; dose reduction in the lungs and breasts were approximately 47% and 30%, respectively.

It is expected that breast shielding would degrade image quality and would increase the image noise, however the results of this work suggests that it may be an acceptable procedure to be used for dose reduction mainly during CT examinations that would provide high doses to radiosensitive organs. Despite the disadvantage in terms of image quality, the use of bismuth shielding is simple and efficient to reduce absorbed doses to the breast and nearby organs. There are some works that argued against the use of bismuth shielding and they recommend the reduction of the

Table 1
Mean absorbed dose in some organ positions in the phantom during thoracic CT scans with and without bismuth shielding on breasts.

Organ position in the phantom	Mean absorbed dose (mGy)		Dose reduction (%)
	Without bismuth shielding	With bismuth shielding	
Right lung	11.5 ± 0.5[a]	6.2 ± 0.5	46.1
Left lung	12.5 ± 0.3	6.4 ± 0.4	48.8
Thyroid	24.3 ± 0.6	12.2 ± 0.9	49.8
Right breast	8.3 ± 0.4	5.8 ± 0.4	30.1
Left breast	8.2 ± 0.5	5.7 ± 0.4	30.5

[a] Standard deviation.

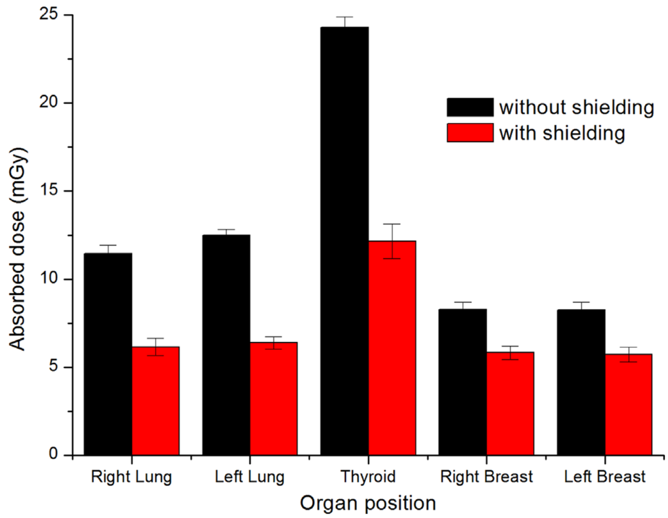

Fig. 3. Influence of bismuth shielding on absorbed doses for some organ positions of the phantom.

tube current, instead (McCollough et al., 2012). It should also be considered that the use of bismuth shielding associated with the automatic exposure control in some CT scanners might increase the doses since the system will adjust the exposure to obtain a good image quality (McCollough et al., 2012).

4. Conclusions

Absorbed doses were determined during thoracic CT scans with and without bismuth shielding on breasts of an Alderson Rando® female anthropomorphic phantom. Dose values were significantly reduced and they suggested that the use of bismuth would be, in some cases, a proper procedure for protection. However, the influence of bismuth on the image quality requires study.

Acknowledgments

T. Ancherythroculter da Silva acknowledges the financial support of FAPEMIG (PPM 0349-13), Brazil and CNPq (PQ 302968/2015-6), Brazil (PQ). This work is part of the project INCT Metrology of Radiation in Medicine.

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