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Analysis of lenses absorbed dose in head CT scan with the use of bismuth shielding

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ABSTRACT

Computed Tomography (CT) has become an important tool to diagnose cancer and to obtain additional information for different clinical questions. However, CT scan usually requires a higher radiation exposure than a conventional radiography examination. Head CT scans are used for diagnosis of traumatic head injuries, infections and other diseases with instability. Based on this information, it was studied the dose variation deposited in the lenses and in nearby organs, such as: pharynx, hypophysis and salivary gland with and without the use of bismuth shield. In this study a head CT scan was performed on anthropomorphic male phantom using a GE scanner. Dose measurements have been performed by using radiochromic film strips to register the individual doses in the organs of interest. The results show us that the lenses had a reduction of 26% of the dose with the use of the bismuth shield.

Keywords: Computed Tomography, Dosimetry, Bismuth shielding.

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1. INTRODUCTION

The Computed tomography (CT) is the most common technique used for diagnostic purpose. It is a very fast test that can be performed in high quality images. However, the increasing demand for CT had a considerable impact on doses provided to patients and on the exposure of the population as a whole [1]. In fact, the worldwide average annual per-capita effective dose from medical procedures has approximately doubled in the past 10-15 years [2]. The dose evaluation in CT is one of many steps that can contribute to reducing patient doses. The head CT scans are commonly used for diagnosis of traumatic head injuries, infections and other diseases with instability, so it can be associated with a high radiation dose to organs such as lenses, salivary gland, pharynx and hypophysis, when compared with conventional radiology. The main objective of this study was to analyze the absorbed doses in a head CT scan with and without the use of bismuth shield in the lenses.

2. MATERIALS AND METHODS

The experiment to observe the reduction on dose due to bismuth shield was conducted using a GE CT scanner, Discovery model of 64 channels. An Alderson Rando male anthropomorphic phantom was used to perform head CT scans from the cervical vertebra C1 to the top of skull. This phantom is composed of a human skeleton surrounded by a material, physically and chemically similar to the soft tissues of an adult human body [3]. The body and head are structured in 2.5 cm thick slices. The slices that make up the body phantom have holes that allow placing dosimeters within the phantom [4, 5]. Fig. 1 shows the positioning of the male phantom in the gantry isocenter.

Figure 1: *Positioning of the Alderson male phantom in the gantry*

A scout was done to check the correct position of the phantom as shown in Fig. 2 that presents the tomogram side of the head. The parameters of the protocol used in this study are shown in Table 1.

Figure 2: *Lateral Scout of head and chest with eye bismuth shielding*

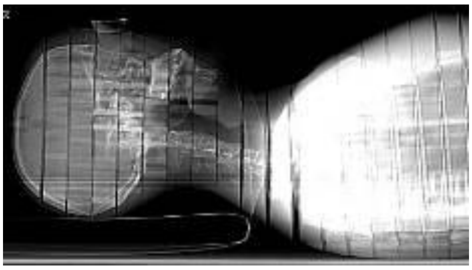


Table 1: CT scan parameters.

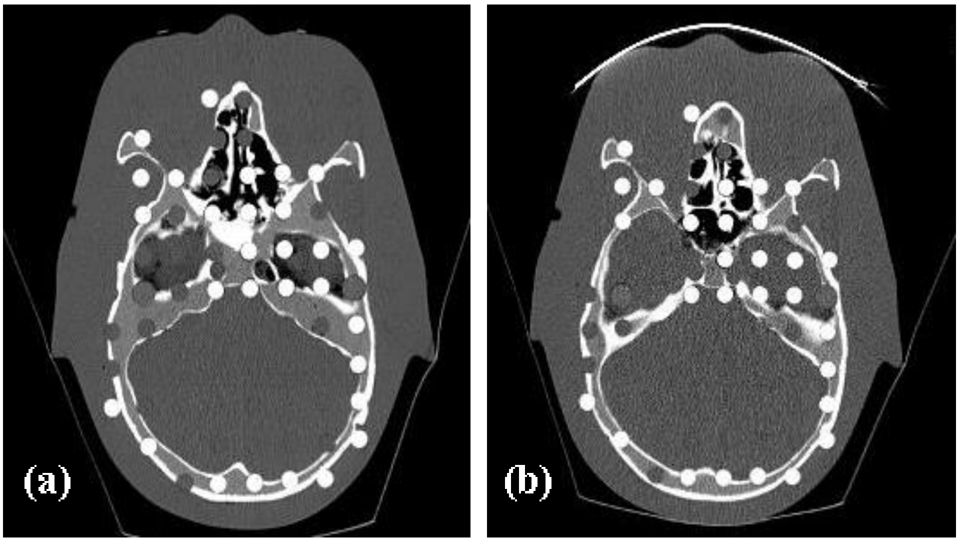
Voltage (kV)	Electric current (mA)	Tube Time (s)	Pitch	Distance (mm)	Thickness beam (mm)
120	175	0.8	0.984	150	40

Dose measurements have been performed by using GAFCHROMIC XR-CT radiochromic film strips to register the individual doses in the organs of interest such as lenses, thyroid, pharynx, hypophysis and salivary gland, with and without bismuth shield on the eyes area (Fig.3).

Fig 4 shows the axial head CT images with and without a 1 mm thick piece of bismuth.

Figure 3: *The Alderson phantom with the bismuth shield on the eye spot and a radiochromic film strip on thyroid*

Figure 4: *Axial head CT images: (a) without and (b) with bismuth shielding over the eyes*



The radiochromic films are self-developing dosimetry films, insensitive to visible light making it easy to work with during analysis and provide greater spatial resolution in the sub-millimeter range (Fig. 5). They have been used extensively in combination with flat bed document scanners to measure patient doses [6,7].

Figure 5: *Radiochromic film strips: (a) background and (b) exposed.*

(a) **(b)**

The exposed films were digitized using a HP Photosmart C4480 reflective type scanner. The scanning parameters used were RGB mode (48 bit) and 300 ppi. The red channel was selected to the measurements because these radiochromic films have a main absorption peak in the red region of the visible spectrum (636 nm) [6,7]. Metrological reliability of the radiochromic films was demonstrated through homogeneity and repeatability tests and by calibrating it in a reference radiation for CT (RQT9) that were reproduced in the Calibration Laboratory of the Center for Development of Nuclear Technology (CDTN/CNEN) [7, 8].

3. RESULTS AND DISCUSSION

Absorbed doses in organ positions such as: thyroid, lenses, pharynx, hypophysis and salivary gland are shown in Table 2. These results allow us to observe that the use of bismuth shield led to a decrease in radiation dose deposited in the eyes as well as in all organs studied.

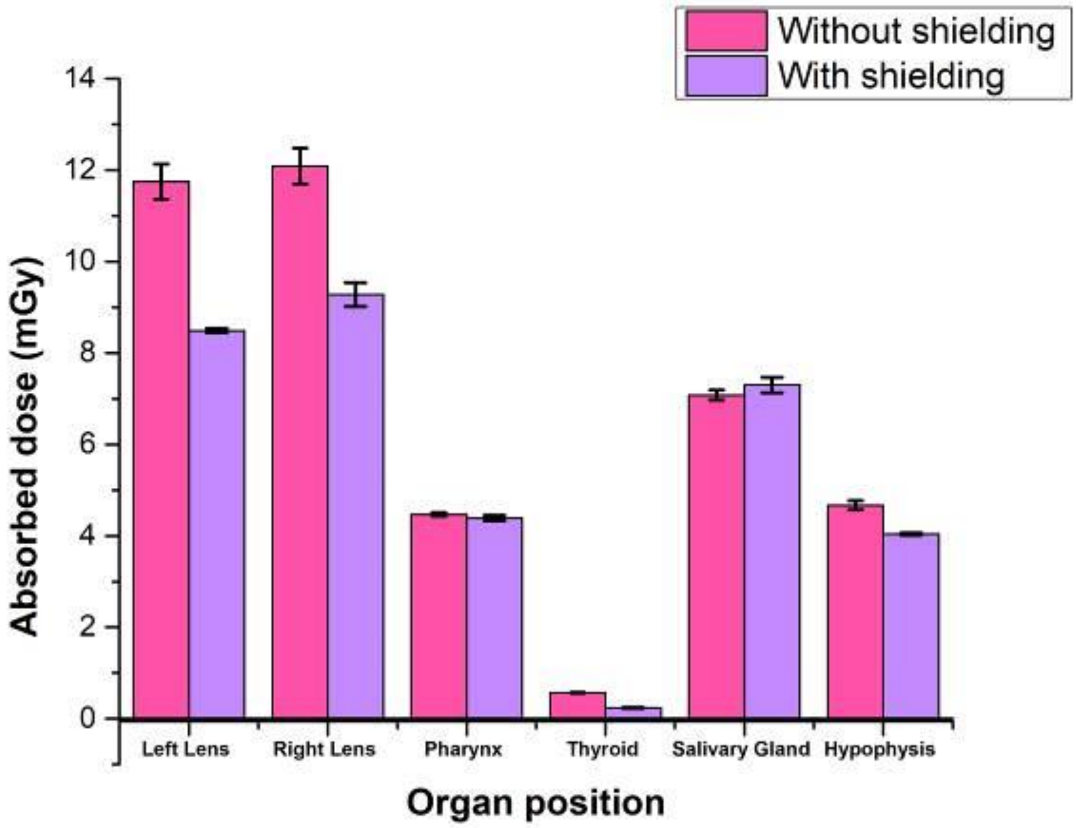
Table 2: Mean absorbed doses in some organ positions in the phantom during head CT scans with and without bismuth shielding on eyes.

Organ position	**Mean absorbed dose (mGy)**		**Dose reduction (%)**
	Without bismuth shielding	**With bismuth shielding**	
Left Lens	11.75 ± 0.38	8.49 ± 0.05	28
Right Lens	12.09 ± 0.39	9.28 ± 0.26	24
Pharynx	4.47 ± 0.04	4.39 ± 0.06	2
Thyroid	0.57 ± 0.01	0.24 ± 0.01	19
Salivary Gland	7.08 ± 0.11	7.30 ± 0.17	3
Hypophysis	4.67 ± 0.10	4.04 ± 0.03	14

[a] Standard deviation.

The highest recorded dose, 12.09 mGy, occurred in the eyes position that stressed the situation of unnecessary radiation exposure. The recorded doses due to scans with and without bismuth shielding showed significant differences. A dose reduction of 28% in the eyes was accomplished due to the use of bismuth shielding. It is expected that eye shielding would degrade image quality and would increase the image noise. However the results of this work suggest that it might be an acceptable procedure to be used for dose reduction mainly during CT examinations that would impart unnecessary high doses to radiosensitive organs (Fig.4). The use of bismuth shielding is simple and efficient to reduce absorbed doses to the eyes and nearby organs. Fig. 6 shows the influence of bismuth shielding on absorbed doses in the organs studied.

Figure 6: *Influence of bismuth shielding on absorbed doses for some organ positions of the phantom*



4. CONCLUSIONS

The absorbed doses were determined during head CT scans with and without bismuth shielding on lenses of an Alderson Rando male anthropomorphic phantom. Dose values were significantly reduced suggesting that the use of bismuth would be, in some cases, a proper procedure for protection as the conditions used for both scans were the same. However, the influence of the use of bismuth shielding on the image quality still requires more detailed studies.

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