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CT DOSE PROFILES AND MSAD CALCULATIONS IN A CHEST PHANTOM

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ABSTRACT

For optimizing patient doses in computed tomography (CT), the Brazilian legislation has only established diagnostic reference levels (DRLs) in terms of Multiple Scan Average Dose (MSAD) in a typical adult as a quality control parameter for CT scanners. Compliance with the DRLs can be verified by measuring the Computed Tomography Air Kerma Index with a calibrated pencil ionization chamber or by obtaining the dose distribution in CT scans. An analysis of the quality of five CT scanners in Belo Horizonte was done in terms of dose profile of chest scans and MSAD determinations. Measurements were done with rod shape lithium fluoride termoluminescent dosimeters (TLD-100) distributed in cylinders positioned in peripheral and central regions of a polymethylmethacrylate chest phantom. The peripheral regions presented higher dose values. The longitudinal dose variation can be observed and the maximum dose was recorded at the edges of the phantom at the midpoint of the longitudinal axis. The MSAD results were in according to the DRL of 25 mGy established by Brazilian legislation. The results contribute to disseminate to hospitals and radiologists the proper procedure to use the termoluminescent dosimeters for the calculation of the MSAD from the CT dose profiles and to notice the compliance with the DRLs.

1. INTRODUCTION

The bases for dosimetry in radiology were launched during the Conference of Malaga, in 2001, aiming at the radiation protection of patients undergoing diagnostic examinations or therapy, both in radiotherapy, radiodiagnostic and nuclear medicine [1].

The use of radiation in medicine has grown due to the benefits associated as for the technological development. An example of such technological development is the new generations of scanners.

Nowadays, in spite of CT scanners used in radiodiagnostic services are of third generation, there are different factors that differentiate them, such as the axial (conventional), helical and helical multislice scans, the variety of manufacturers and different tube potential, tube current and time values.

Each service, regardless of the type of scanner used, adopts its own protocol, and this is the principal reason for differences between the image acquisition protocols.

Many countries have introduced in their legislation the obligation of reporting the doses imparted to the patients undergoing radiodiagnostic examinations. The Brazilian legislation established diagnostic reference levels (DRLs) in terms of the Multi Slice Average Dose (MSAD) as 50 mGy for head, 35 mGy for lumbar spine and 25 mGy for abdomen/chest in a typical adult patient [2].

As part of an optimization program, DRLs should be used for quality control of CT scanners to review and adjust procedures and techniques when doses exceed the specified values [2]. DRLs values were adopted from international recommendations [3] and they may not represent the actual conditions of Brazilian examinations.

In Minas Gerais state, quality control CT tests are mandatory since July 1, 2009, but a better understanding of the methodology to perform such tests is still needed.

The CT Air Kerma Index ($C_{a,100}$), the weighted CT air kerma index (C_w) and the Air Kerma - Length Product (P_{KL}) are dosimetric quantities recommended for CT dosimetry [1].

In this work, experimental measurements in a chest/body PMMA phantom with thermoluminescent (TL) dosimeters were performed for obtaining dose profiles generated by five CT scanners in Belo Horizonte.

2. METHODOLOGY

Measurements were done in five CT scanners (Tab. 1) located in hospitals of Belo Horizonte with the standard image protocols for adult chest.

Table 1. Specification of scanners used in this work

CT Scanner	Manufacturer	Model
SI	Philips	Brilliance
SII	GE	Bright Speed
SIII	Philips	Brilliance
SIV	GE	Light Speed
SV	GE	Bright Speed

Rod shape LiF: Mg, Ti (TLD-100) TL dosimeters, with 1 mm in diameter and 6 mm in length, and a model 4500 Harshaw TL reader were used for the measurements. The metrological reliability of the TL system was demonstrated through reproducibility and homogeneity tests of the batch and by calibrating it in a reference radiation for tomography (RQT9) that were reproduced in the Calibration Laboratory of the Development Center of Nuclear Technology (CDTN/CNEN).

Dose profiles were obtained in a PMMA body phantom, with 32 cm in diameter and 15 cm in length, with five parallel holes in depth (one in the center and the others at the periphery, corresponding to 12h, 3h, 6h and 9h positions) (Fig. 1).

TL dosimeters were placed each 10 mm along the PMMA cylinders and two dosimeters were placed 2 mm from the center (Fig. 2).

The phantom with TL dosimeters was positioned with the help of lasers, in the isocenter of the CT scanners (Fig. 3).

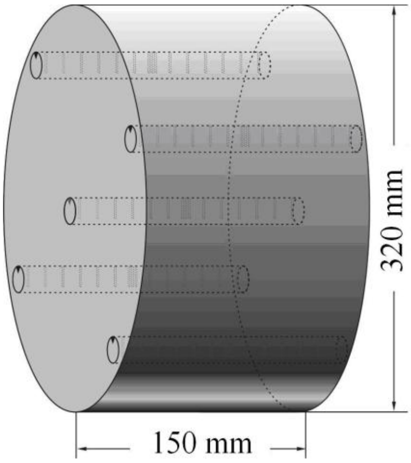

Figure 1. Body PMMA phantom for CT dosimetry.

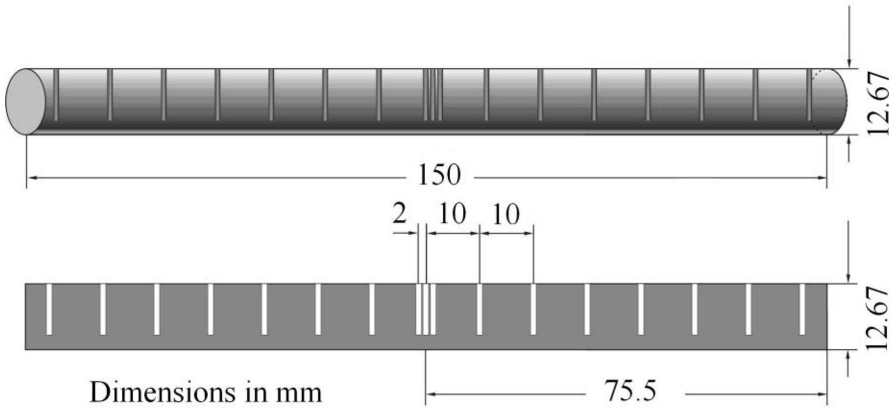

Figure 2. PMMA cylinder for positioning the TL dosimeters.

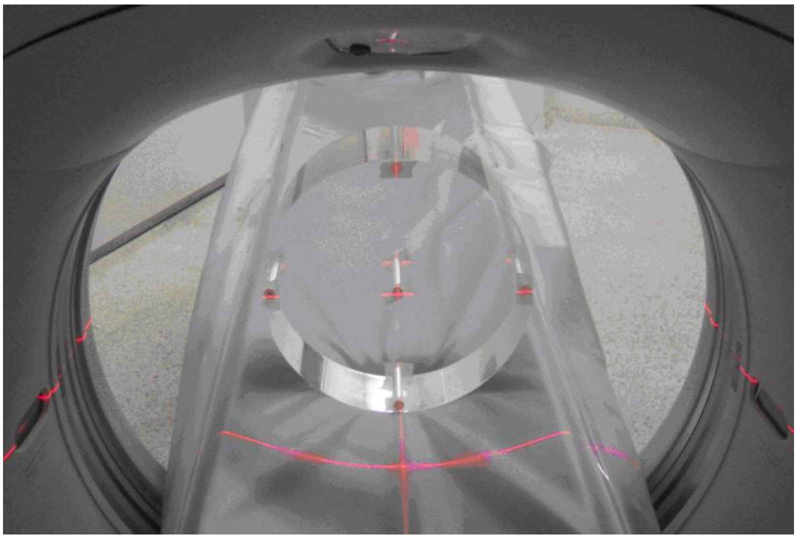

Figure 3. Positioning of the PMMA phantom in the scanner isocenter.

A scout was done to check the positioning of the phantom and demarcate the area of the irradiation to be performed. The scan parameters are shown in Tab. 2.

Table 2. Scan Parameters

CT Scanner	kV	Beam Thickness (mm)	mA.s	Pitch
SI	120	16 x 0.750	250.0	0.938
SII	120	4 x 2.500	240.0	0.750
SIII	120	16 x 2.000	310.0	1.000
SIV	120	16 x 0.625	237.6	1.750
SV	120	4 x 2.500	282.0	0.800

3. RESULTS AND DISCUSSION

The pre-selected batch of TL dosimeters had a uniformity of 18.6% and a reproducibility of 7.8%, these values complied with international requirements [4]. The calibration coefficient in terms of air kerma of the TL dosimeters for RQT9 (120 kV) was (61.2±10.3) $\mu Gy.nC^{-1}$ (coverage factor, k = 2.08). Measurements were converted to absorbed dose in PMMA with the air to PMMA attenuation coefficient ratio equals to 1.0682 [5].

Dose profiles along the longitudinal axis in the five positions of cylinders inserted in the phantom for five CT scanners are shown in Fig. 4 to 8.

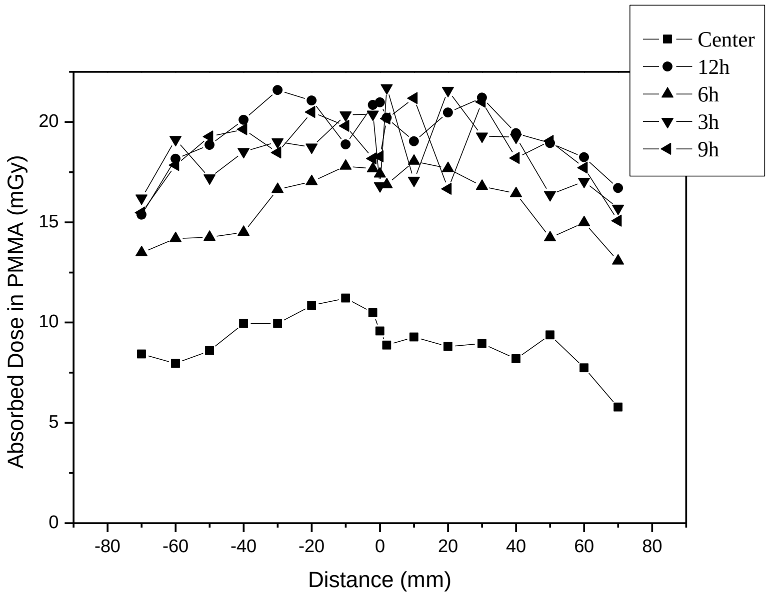

Figure 4. Dose variation of SI along the longitudinal axis of five positions in the PMMA phantom.

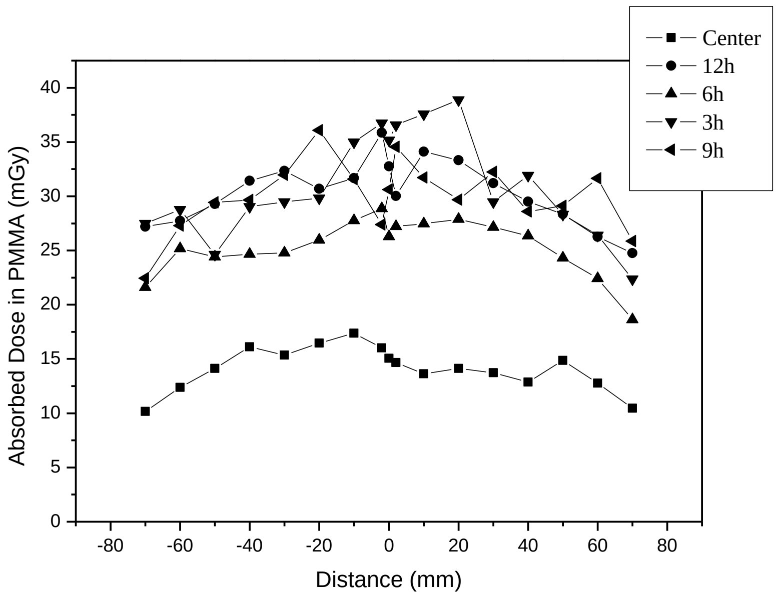

Figure 5. Dose variation of SII along the longitudinal axis of five positions in the PMMA phantom.

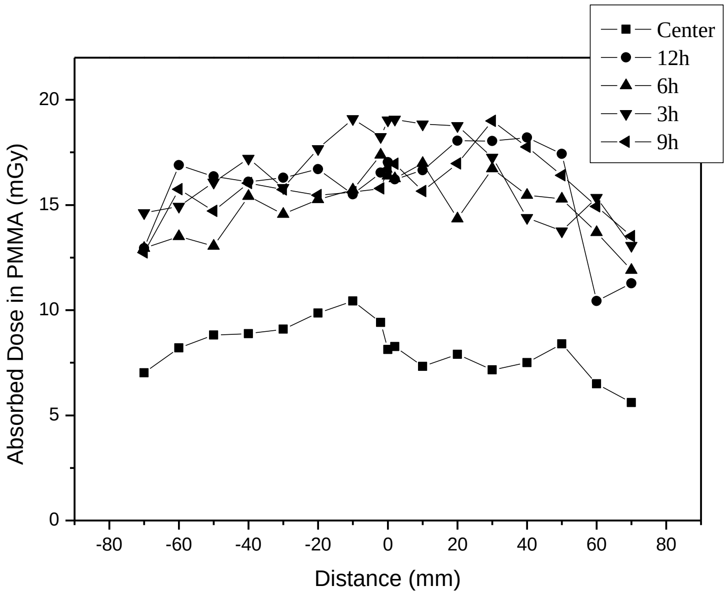

Figure 6. Dose variation of SIII along the longitudinal axis of five positions in the PMMA phantom.

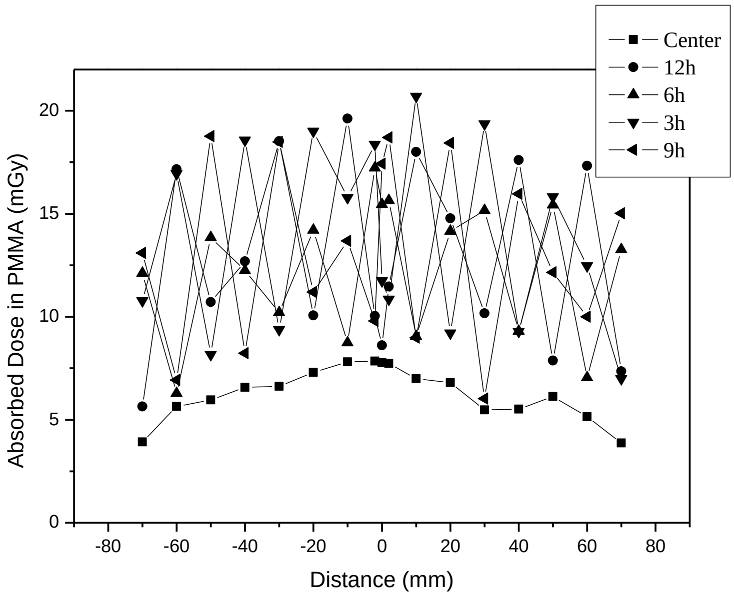

Figure 7. Dose variation of SIV along the longitudinal axis of five positions in the PMMA phantom.

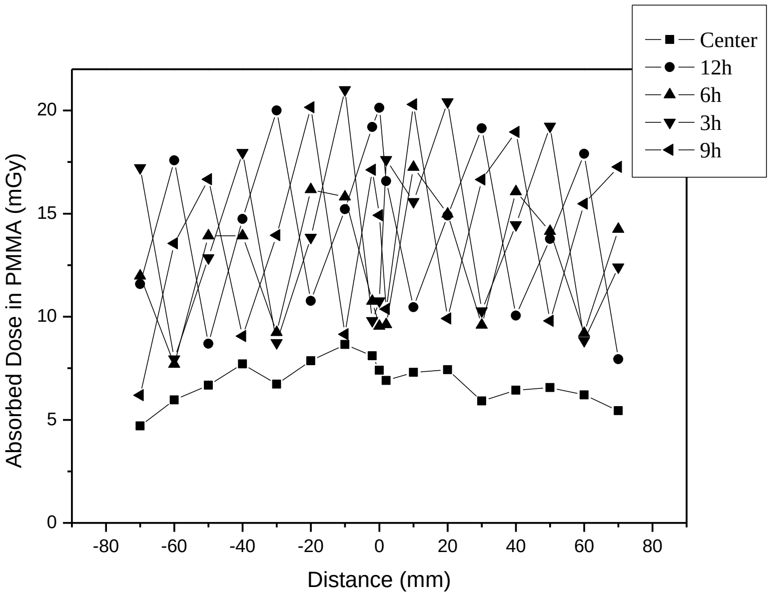

Figure 8. Dose variation of SV along the longitudinal axis of five positions in the PMMA phantom.

The absorbed dose in PMMA measured with three TL dosimeters close to the midpoint of the central cylinder inserted in phantom were 9.6±2.4, 15.2±3.5, 7.5±1.9, 8.6±2.1 and 7.8±1.8 mGy (k = 2.07), for CT scanner I to V, respectively.

The results showed the dose variation in the phantom. The peripheral regions of the phantom presented dose values higher than the central regions, in a proportion of 2:1. This is explained by the X rays attenuation through the phantom.

The 6h regions showed the lowest dose in comparison to other peripheral regions due to attenuation in the table of the CT scanners, except in cases SIII and SIV of CT scanners which their modern tables do not cause a high attenuation of the X rays.

By analyzing the measurements in the PMMA cylinders, the longitudinal dose variation can be observed. The highest doses are in the central regions due to the significant contribution of scattered radiation generated in the scans. The highest dose was recorded at the edges of the phantom at the midpoint of the longitudinal axis.

Due to the wide dispersion of results in SIV and SV, it is difficult to make a correct analysis of their dose profiles. This large variation is due mainly to influence of pitch and the lost of sensitivity of some TL dosimeters.

The integral values corresponding to the curves of central regions of the phantom and the calculated MSAD results from an integration interval of -70 to +70 mm are shown in Tab. 3.

Table 3. Integral Values and MSAD Results

CT Scanner	Integral Value	MSAD (mGy)
SI	1275.1	9.1 ± 1.7
SII	1994.2	14.2 ± 2.6
SIII	1150.6	8.2 ± 1.5
SIV	877.3	6.3 ± 1.2
SV	958.6	6.8 ± 1.2

The calculated MSAD results are in according to the DRL of 25 mGy established by Brazilian legislation. The DRLs should be used as part of an optimization program to review and adjust procedures and techniques when doses exceed the specified values.

The average absorbed dose values of the peripheral results of the PMMA phantom demonstrate the dose variation with the respective standard deviations in the five CT scanners studied (Fig. 9).

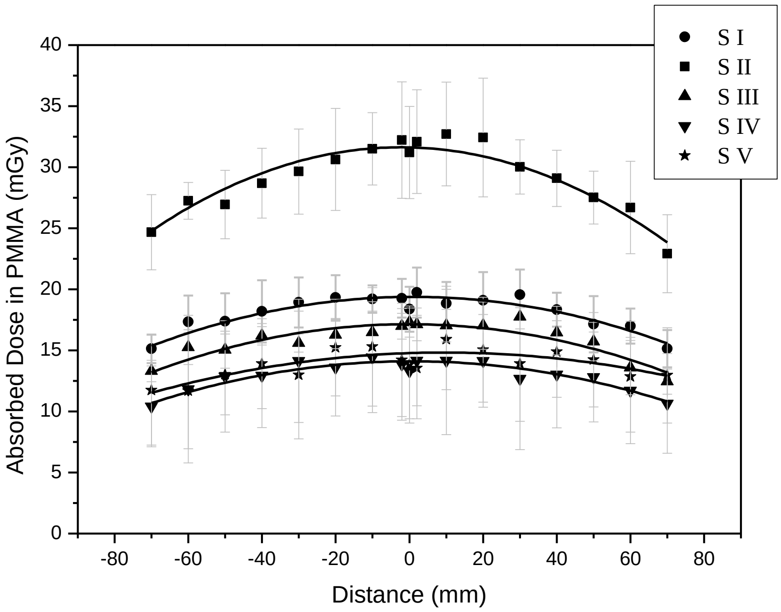

Figure 9. Comparison of the variation of the average doses in the longitudinal axis of the peripheral cylinders in the five CT scanners studied.

SII has the higher dose compared with other CT scanners. The difference between the five CT scanners is due to the protocol used at each service. SIV and SV are models of GE and have a closer dose profile. The difference is due to SIV to have more channels, to be faster and to have a higher pitch. The difference between the CT scanners from GE and SII is due to the beam thickness. SI and SIII are models from Philips and have a closer dose profile. The difference is due to SI to have a shorter time and a shorter mA.s.

4. CONCLUSIONS

The results of this work contribute to disseminate to hospitals and radiologists the proper procedure to use the termoluminescent dosimeters for the calculation of the MSAD from the CT dose profiles and to notice the compliance with the DRLs.

The calculated MSAD results are in according to the DRL of 25 mGy established by Brazilian legislation. Other results suggested that the DRLs may be too high and they do not represent the actual conditions of Brazilian examinations.

TL dosimeters have some advantages for dose profile measurements like the possibility of reusing and the acceptable cost. The disadvantages are the difficult handling, high uncertainty (~18.3%) and non-continuous reading.

Considering that TL dosimeters have been used for dosimetry in radiology in Brazil, this work contributes to disseminate that the use of these materials is feasible with care and the DRLs must be revised.

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