Available online at www.sciencedirect.com

ScienceDirect

Nuclear Instruments and Methods in Physics Research B 266 (2008) 107–110

NIM B
Beam Interactions with Materials & Atoms

www.elsevier.com/locate/nimb

A rotational calibration method using thermoluminescent dosemeters for dose determination in computed tomography beams

Ana F. Maia [a,b,*], Linda V.E. Caldas [b]

[a] Departamento de Física, Universidade Federal de Sergipe, Av. Marechal Rondon, s/n, CEP 49100-000, São Cristóvão – SE, Brazil
[b] Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear, Av. Prof. Lineu Prestes, 2242, CEP 05508-000, São Paulo – SP, Brazil

Received 27 July 2007; received in revised form 8 October 2007
Available online 22 October 2007

Abstract

A procedure for calibration of thermoluminescent dosimeters, called rotational calibration, was developed to create a procedure more adequate for dose procedures used in computed tomography. Thermoluminescent dosimeters were rotated during irradiation to simulate the set-up used in dosimetric procedures in computed tomography equipment. Three commercial types of thermoluminescent dosimeters were calibrated using this methodology. The results showed that the measured values were lower when the dosimeters were irradiated with rotation than in a static geometry. Although the reading differences were not very large, they are not negligible, and they contribute to underestimating the dose.

PACS: 29.40.Wk

Keywords: Thermoluminescent dosimeters; Angular dependence

1. Introduction

The dosimeters used in computed tomography (CT) dosimetric procedures should not have a significant angular dependence, because the X-rays tube rotates around the table couch. The most utilized dosimeter in CT is the pencil ionization chamber, which is a cylindrical ionization chamber with a uniform response around its central axis [1]. However, thermoluminescent dosimeters (TLD) have also been used in CT beams [2–4]. In dose determination procedures with TLDs in CT beams, no references were found for correction factors utilized to compensate the effect of the angular dependence of dosimeters. Janeczek and Pernicka [3] compared the dose measured in four types of different CT equipment using TL dosimeters and a CT ionization chamber, but the angular dependence of the TLDs was not considered.

The dosimetric procedure performed with TLDs consists mainly of two parts, calibration of the TLDs in a standard beam where the air kerma rate is well known, and measurements with the TLDs in the clinical beams. In the conventional calibration method, the dosimeter is static, with only one side directly facing the primary beam.

The aim of this study was to determine the effect of angular dependence in the measurements performed with commercial TLDs, and so to verify if the conventional method of TLD calibration is adequate for dose determinations in CT.

2. Materials and methods

Two methods for the determination of TLD calibration curves were compared to evaluate the influence of the

---

[*] Corresponding author. Address: Departamento de Física, Universidade Federal de Sergipe, Av. Marechal Rondon, s/n, CEP 49100-000, São Cristóvão – SE, Brazil. Tel.: +55 79 2105 6810; fax: +55 79 2105 6636.

E-mail addresses: afmaia@fisica.ufs.br (A.F. Maia), lcaldas@ipen.br (L.V.E. Caldas).

0168-583X/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.nimb.2007.10.008

angular dependence in the TL response. The conventional method is where only one side of each dosimeter is irradiated, and a rotational method where the dosimeters were kept rotating during irradiation, simulating clinical beams.

Three types of TLDs were tested: LiF:Mg, Ti(TLD-100), CaF_2:Dy(TLD-200) and CaF_2:Mn(TLD-400) from Harshaw Chem. Co. The pellets have the dimensions of 3 mm × 3 mm × 0.9 mm. For the TL measurements a Harshaw Nuclear System, model 2000A/B, was utilized. All TLDs were evaluated with a linear heating rate of 10 °C/s, using a constant flow of high purity nitrogen of 5.0 l/min.

The thermal treatment applied to the TLDs prior to irradiation was 400 °C for 1 h [5]. For the TLD-200 a post-irradiation thermal treatment at 115 °C for 10 min was also applied to eliminate the low temperature peak (120 °C, 140 °C) contributions, which present a high thermal fading.

The irradiation support was fixed to a commercial blender and coupled to a voltage regulator, allowing rotation of the TLDs with a controlled speed of 80 rpm. This is similar to that of modern CT equipment where X-ray tube rotation time intervals are between 1 and 3 s [6,7]. Irradiation of the TLDs by the conventional method was realized with the same set-up, with no rotation. The details of the irradiation set-up are shown in Fig. 1. Four TLDs of each type were used for the measurements, positioned in a line perpendicular to the cathode–anode direction to avoid contribution of the heel effect. The results shown are those determined by considering the response of four TLDs.

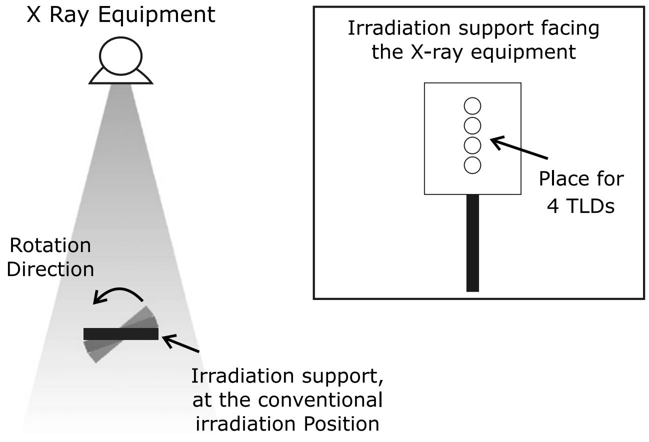

Fig. 1. Irradiation set-up showing the rotation direction and, in the inset, the position of the TLDs in the irradiation support.

Besides the calibration curves, energy dependence curves were also obtained with and without rotation. The materials were irradiated in diagnostic radiology standard beams with parameters listed in Table 1. The reference system for these qualities, which was calibrated in air kerma, was a parallel-plate ionization chamber with 1 cm^3 of sensitive volume, PTW, model 77334, with a PTW electrometer, model UNIDOS 10001. This chamber was calibrated at the German primary standard laboratory, Physikalisch-Technische Bundesantstalt (PTB).

3. Results

The RQA9 standard beam was used for determining the calibration curves over a dose range from 1 to 50 mGy. The mean curve obtained in each methodology is shown in Fig. 2. For all studied materials, the TLD response in the rotation irradiation methodology was always lower than in the conventional irradiation methodology.

For the energy dependence study of the TL materials response, all standard beams in Table 1 were used. The reference beam for CT was the RQA9 quality. The energy dependence curves obtained for each type of TLD are shown in Fig. 3. The TLD response in the rotation irradiation methodology was always lower than that without rotation.

The overall uncertainties in all tests were estimated following the ISO-GUM recommendations [8]. Various parameters, such as TL reproducibility, uncertainties in the TL reader and in the irradiation time, were considered. The expanded uncertainty obtained considering a coverage factor of 2 was estimated as 7.2%.

The differences between the data in Figs. 2 and 3 are shown in Table 2. These values represent the variation in the TL intensity for each irradiation condition between the two methodologies. They were obtained from:

$$\text{Percentage difference} = \frac{TL_{\text{direct}} - TL_{\text{rotational}}}{TL_{\text{direct}}} \times 100\%.$$

The mean percentages ranged from 4.2% to 6.9% for the calibration curves, and from 3.3% to 4.9% for the energy dependence curves. Comparing these results with the uncertainties (7.2%), in the majority of cases the percentage differences are within the uncertainty range. Therefore, the results do not allow a definitive conclusion. However, they indicate strongly that the angular dependence of the TL response is significant. Moreover, the final measurement

Table 1
Characteristics of diagnostic radiology qualities, attenuated beams, at the Pantak/Seifert X-ray equipment, model ISOVOLT 160HS

Radiation quality	Voltage (kV)	Half-value layer (mm Al)	Effective energy (keV)	Air kerma rate (mGy/min)
RQA6	80	8.13	54.75	3.99
RQA7	90	9.22	59.70	4.87
RQA8	100	10.09	63.95	5.76
RQA9	120	11.39	71.15	7.93
RQA10	150	13.02	82.10	13.28