Application of the thermoluminescent technique for calibration and dosimetry of $^{90}Sr+^{90}Y$ applicators

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Abstract

Dermatological and ophthalmic applicators are used in brachytherapy for the treatment of superficial lesions of skin and eyes. The calibration of these applicators should be realized periodically, according to quality control programs and international recommendations about dosimetry and calibration of brachytherapy sources. Thin thermoluminescent dosimeters of $CaSO_4$:Dy were utilized in this work for the calibration of different applicators using a dermatological applicator as reference. The absorbed dose rates obtained were compared with those of their calibration certificates. Depth dose curves were obtained for all applicators using absorbers of different thicknesses.

Keywords: $^{90}Sr+^{90}Y$ clinical applicators, thermoluminescent dosimetry, depht dose curves

1. Introduction

The calibration and dosimetry of $^{90}Sr+^{90}Y$ clinical applicators have become important procedures. These beta-ray sources are utilized in brachytherapy since 1950, when they were developed by Friedell et al. (1950), for the treatment of superficial lesions of the skin and eyes. The dermatological applicators can be used in the treatments of keloid, a scar that forms on skin, while the ophthalmic applicators are used in post-operatory treatments of pterigium. The plane (dermatological) and curve (ophthalmic) applicators should be periodically calibrated according to quality control programs and international recommendations, as IAEA (2002) and ICRU (2004), and also, cited in previous papers of De Almeida et al. (2000) and Soares et al. (2001).

The thermoluminescent dosimeters (TLDs) present several applications in radiation dosimetry: environmental, personnel, medical dosimeter and radiation processing, according to Soares (2002). In the medical area, their utilization is recommended for calibration and dosimetry of brachytherapy sources (Soares et al., 2009). TLDs have been used mainly due to the source geometry. In a previous work of Oliveira and Caldas (2004) the performance of several thermoluminescent materials was studied in standard beta radiation fields of the Calibration Laboratory of IPEN (LCI). Oliveira and Caldas (2007) observed that $CaSO_4$:Dy thin pellets presented the best response for beta radiation dosimetry of a $^{90}Sr+^{90}Y$ source.

2. Materials and methods

In this work, different $^{90}Sr+^{90}Y$ sources were utilized: a radiation source of the beta secondary standard system of Buchler GmbH & Co., BSS1, Germany (1850 MBq, 1981), and seven clinical applicators, from which five were dermatological (NIST, A, B, D and E, all planes), one ophthalmic (F, curve) and one dermatological/ophthalmic (C, softly curve). The applicators C, D, E and F present calibration certificates from Amersham. The characteristics of these applicators are presented in Table 1. Three dermatological applicators are from LCI: the NIST applicator, calibrated at the primary standard laboratory of the National Institute of Standards and Technology, USA, applicator A with a calibration certificate of Amersham, England, and applicator B, without any calibration certificate. The applicators C, D, E and F were gently lent by clinics and research institutes.

Table 1
Characteristics of $^{90}Sr+^{90}Y$ clinical applicators

Clinical applicator	Manufacturer and model	Nominal absorbed dose rate (Gy/s)	Calibration date
NIST	*Atlantic Research Comporation*/ B-1 S/N 233	0.40 ± 0.02	28.01.2003
A	*Amersham*/ SIQ 18	0.056 ± 0.011	08.11.1968
B	no certificate		
C	*Amersham*/ SAI 20	0.438*	31.07.1996
D	*Amersham*/ SIQ 21	0.053*	17.09.1986
E	*Amersham*/ Sr 5072 2096	0.04*	14.05.2003
F	*Amersham*/ SAI 6/1418	0.03*	14.05.2003

*no uncertainties presented in their calibration certificates

In this work, thin $CaSO_4$:Dy samples were used, with 6.0 mm of diameter and 0.2 mm of thickness. The pellets were irradiated using the source of the BSS1 system positioned at 11.0 cm of distance using a PMMA base. The dosimeters were also exposed to all clinical applicators. Each pellet was positioned on a phantom, allowing a null distance between the dosimeter and the applicator. The $CaSO_4$:Dy pellets were thermally treated (300 °C/3 h) and cooled quickly for their reutilization. The measurements were obtained utilizing a TL reader from Harshaw Nuclear System, model 2000A/B, with a linear heating rate of 10 °C/s; the reading cycle was performed within 30 s. The light emission was integrated in the temperature interval of 180 °C to 350 °C, as suggested by Campos and Lima (1987).

3. Results

The samples were studied in relation to the reproducibility of their TL response, linearity of the dose response curve, lower detection limit, and depth dose curves were also obtained.

3.1. Reproducibility study

The reproducibility of the TL response of $CaSO_4$:Dy pellets was obtained after 5 series of measurements and thermal treatments. The dosimeters were irradiated with a dose of 1.0 Gy, utilizing the $^{90}Sr+^{90}Y$ source of the BSS1system. The maximum percentual deviation obtained for the dosimeters was 4.1 %. The uncertainty associated was equal to 10.4 %.

3.2. Dose-response curve of NIST applicator

The $CaSO_4$:Dy samples were irradiated using the NIST applicator, utilized as reference in the dose interval from 5 Gy to 20 Gy. The TL response of the dosimeters was obtained in relation to the absorbed dose in air, utilizing a null source-detector distance, and the results can be observed in Fig. 1. Linearity of the TL response was obtained in the whole tested dose interval.

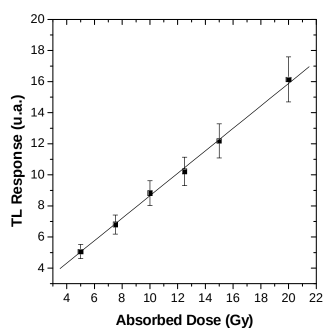

Fig. 1. Dose response curve for the $CaSO_4$:Dy thin pellets irradiated with the NIST applicator ($^{90}Sr+^{90}Y$).

3.3. Calibration of the clinical applicators

The $CaSO_4$:Dy pellets were irradiated using the clinical applicators A, B, C, D, E and F during time intervals of 330, 330, 25, 300, 240 and 360 s, respectively, at a null source-detector distance. Using the dose-response curve, the absorbed dose rates were obtained. The results obtained can be observed and compared with the results presented in the calibration certificates (corrected for radiation decay) in Table 2.

Table 2
Absorbed dose rates obtained to $CaSO_4$:Dy applicators at null source detector distance.

Clinical applicators	Absorbed dose rate (certificate) (Gy/s)	Absorbed dose rate (this work) (Gy/s)
A	0.0213 ± 0.0043	0.0281 ± 0.0058
B	-	0.0322 ± 0.0027
C	0.3245	0.5364 ± 0.0646
D	0.0299	0.0397 ± 0.0056
E	0.0349	0.0420 ± 0.0031
F	0.0257	0.0307 ± 0.0027

Applicator C shows a great difference between both absorbed dose rates, probably due to the fact that the applicator is ophthalmic and also due to lack of uniformity on the surface of the source. Furthermore, a previous work of Soares (1995) shows differences between the calibration by manufacturer and by NIST of approximately 20% for Amersham applicators. Therefore, due to the uncertainties from Amersham calibration certificates and from the measurements (this work), the uncertainties obtained for the absorbed dose rates may be considered satisfactory.

3.4. Lower detection limit

The lower detection limit was obtained by the verification of the variability of the TL response of non-irradiated pellets. The limit obtained for the $CaSO_4$:Dy samples was 77,2 μGy; this value presented the same quantity order of the results obtained by Campos and Lima (1987) of 30 μGy.

3.5. Depth dose curves

The distribution of the dose in depth of water was determined using the $CaSO_4$:Dy pellets. For this study, seven acrylic plaques of 1.0, 1.5, 2.0, 2.5, 3.0, 4.0 and 5.0 mm of thickness, and 5.4 cm of diameter were utilized. The pellets were positioned on an acrylic phantom and the applicator was positioned vertically on the dosimeters.

The results obtained were normalized to water equivalent thickness and to 1.0 mm of depth thickness, as recommended by the IAEA standard (2002). The depth dose curves obtained for all applicators can be observed in Fig. 2.

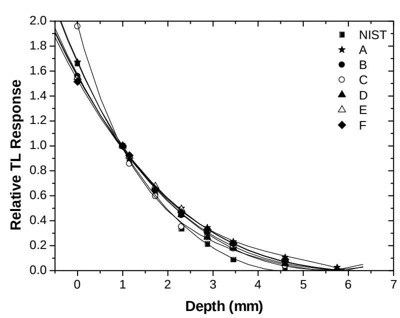

Fig. 2. Depth dose curves obtained to applicators studied and utilizing $CaSO_4$:Dy dosimeters, normalized to water equivalent and to 1.0 mm

The results obtained show that the difference between the values obtained for the applicators and the values given by the standard IAEA (2004), at null depth, were similar; they presented a variation of 4.7% (NIST applicator) and 11.0% (B applicator). For the 0 mm to 3.0 mm thickness, the maximum variation was 38.6% (NIST applicator). For the thickest plaque, great variations were obtained because the absorbed dose in thickness above 4.0 mm is very low. The maximum percentual deviation obtained was 33.4%.

4. Conclusions

The reproducibility study of the TL response presented satisfactory results. The absorbed dose rates were obtained for all six clinical applicators, and they were satisfactory, taking into consideration uncertainties and the lack of uniformity of the radioactive material of the applicators. Depth dose curves were obtained for all applicators, presenting similar results when compared to the results of the NIST $^{90}Sr+^{90}Y$ standard applicator. Therefore, the $CaSO_4$:Dy thin dosimeters are adequate for calibration and dosimetry of $^{90}Sr+^{90}Y$ clinical applicators.

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