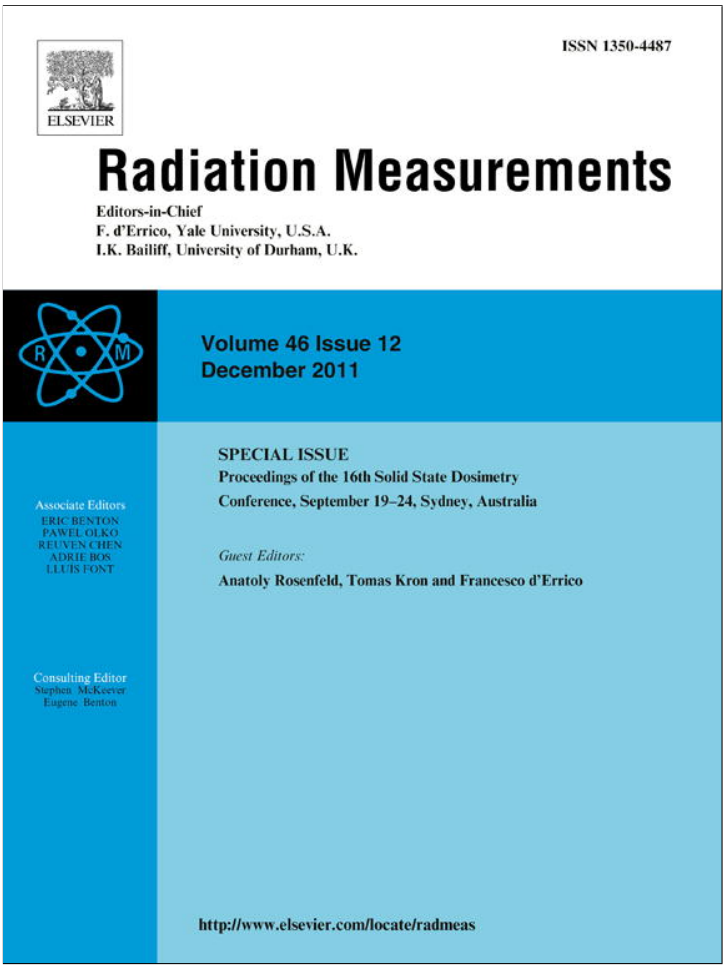

Radiation Measurements 46 (2011) 2025–2027

Contents lists available at ScienceDirect

Radiation Measurements

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

Application of a dosimetric system for calibration of $^{90}Sr+^{90}Y$ sources used in brachytherapy

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ARTICLE INFO

Article history:
Received 3 November 2010
Received in revised form
21 March 2011
Accepted 23 May 2011

Keywords:
Calibration
Thermoluminescent dosimeters
Clinical applicators
Beta radiation

ABSTRACT

$^{90}Sr+^{90}Y$ sources used in betatherapy procedures are still used in Brazilian radiotherapy clinics and hospitals, although these sources are not commercialized anymore. These sources have to be periodically calibrated; a dosimetric system with thin $CaSO_4$:Dy pellets was developed for this purpose. The objective of this work was to apply the dosimetric system in some clinics and hospitals of São Paulo city, as training for the users to calibrate the sources and for a future application of the dosimetric system as a postal system. The results obtained were satisfactory, and they presented an acceptable difference between the results obtained in this work and the values provided in the calibration certificates of the beta sources, when compared with the results obtained in a previous work.

1. Introduction

The thermoluminescent technique has been applied for calibration and dosimetry of $^{90}Sr+^{90}Y$ sources used in betatherapy procedures, also called clinical applicators. TL dosimeters present usefulness for several applications (Soares, 2002), and advantages as easy handling and simple readout (Olko, 2010), for example. Therefore they are useful as radiation detectors.

Clinical applicators are plane if they are utilized for keloid treatments, or concaves when they are used for pterigium treatments. These sources can also be used in esthetical procedures, when the patient was submitted to surgery and would like to prevent the formation of keloids.

International recommendations (IAEA 2002, ICRU 2004) presented the importance of the calibration of $^{90}Sr+^{90}Y$ sources, as part of a quality control program for brachytherapy. Furthermore, authors as De Almeida et al. (2000) and Holmes et al. (2009) also reported about the need of calibrating these sources. Soares (1995) demonstrated that there may be found great differences between the calibration performed by the manufacturer of the clinical applicators and the calibration realized in the primary standard laboratory at the National Institute of Standards and Technology (NIST). Soares et al. (2001) showed also the use of TLDs in the calibration and dosimetry of $^{90}Sr+^{90}Y$ sources used in brachytherapy. In 2007, Oliveira and Caldas (2007) demonstrated that thin $CaSO_4$:Dy pellets are useful for the calibration of these clinical applicators.

Although these sources are not commercialized anymore, they are still in constant use in many Brazilian radiotherapy hospitals and clinics, showing their importance. There are several places that already realize betatherapy treatment with linear accelerators, but the plane or concave plaques are still the most utilized equipment in Brazil for superficial treatments of the skin and the eyes.

Antonio and Caldas (2009) developed a postal dosimetric system for calibration of $^{90}Sr+^{90}Y$ dermatological and ophthalmic applicators of radiotherapy clinics of São Paulo city, using thin $CaSO_4$:Dy pellets. The objective of this work was to apply the developed dosimetric system at these clinics and hospitals, as a training program of the clinical applicator operators, and to calibrate the sources, with the posterior emission of a calibration certificate for each source. In a near future, this dosimetric system shall be utilized in São Paulo and in other Brazilian states as a postal system.

2. Materials and methods

The dosimetric system was developed using thin thermoluminescent dosimeters of $CaSO_4$:Dy, with 6.0 mm of diameter and 0.2 mm of thickness, produced at the Dosimetric Materials Laboratory of IPEN. The dosimetric kit is composed by TL detectors, a chronometer, gloves, an aluminum support for the dosimeters, a PMMA support to fix the pellets, a clamp, a form to be filled with

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doi:10.1016/j.radmeas.2011.05.049

the information about the sources and the calibration procedure. During this work, the operators of the clinical applicators at several clinics were trained about how to use the dosimetric system.

A $^{90}Sr+^{90}Y$ source of the secondary standard system of Buchler GmbH & Co., model BSS1, Germany (1850 MBq, 1981) was utilized for the reproducibility study of the TL pellets. A $^{90}Sr+^{90}Y$ clinical applicator, calibrated at the American Primary Standard Laboratory of the National Institute of Standards and Technology (NIST), called therefore NIST applicator, was used for the irradiations as reference source.

During the calibration procedures, the TL pellets were exposed to different $^{90}Sr+^{90}Y$ applicators of the hospitals; for this procedure, a PMMA support with dimensions of 5.0 cm of diameter and 1.0 cm of thickness was utilized. The distance between each sample and each source was null. During the calibration, the sources were positioned using an adequate support. Between each TL sample and the source, a plastic film of superficial density of 1.095 mg/cm^2 was utilized.

Five radiotherapy hospitals were visited and fourteen clinical applicators were calibrated. As the sources are very old, some of them, as in the case of Hospital 2, do not have the original certificate anymore, but only some files with source information. However, it is known that all of they were manufactured by Amersham International. The characteristics of the sources can be observed in Table 1.

The TL measurements were obtained using a Harshaw TLD Reader model 3500, with light emission integrated in the temperature interval between 180 °C and 350 °C. All TL measurements were taken just after the irradiations; afterwards, the pellets were thermally treated at 300 °C during 3 h for reutilization.

3. Results

Initially, the reproducibility of the TL response of the $CaSO_4$:Dy pellets and the lower detection limit were determined. The dose-response curve was obtained for the samples using the NIST applicator as reference, and the absorbed dose rates were determined for each source.

3.1. Reproducibility study of thin CaSO4:Dy pellets

The reproducibility of the TL pellets was obtained after five series of irradiations (1 Gy), measurements and thermal treatments. The maximum percentage deviation obtained was equal to 7.1%, and the associated uncertainty was 8.7% (Antonio et al., 2010).

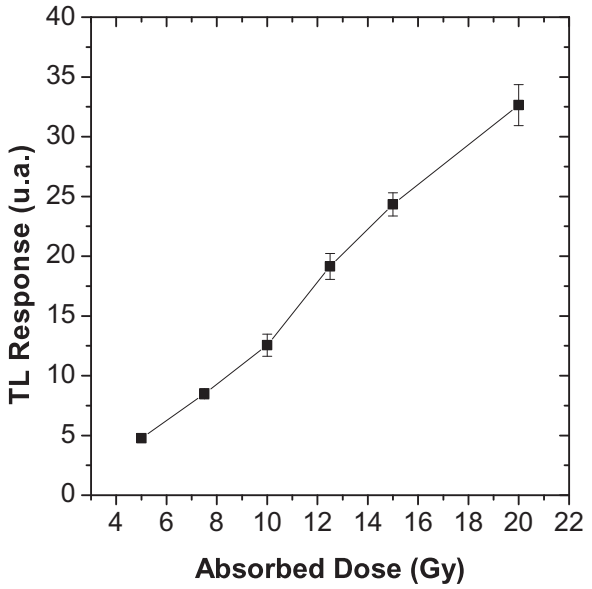

Fig. 1. Dose-response curve of the thin $CaSO_4$:Dy pellets, using the reference $^{90}Sr+^{90}Y$ NIST applicator.

3.2. Lower detection limit

The lower detection limit was determined by studying the variation of the TL response of non-irradiated $CaSO_4$:Dy samples. The limit obtained for the TLD dosimeters was 56 μGy (Antonio et al., 2010), presenting the same order of magnitude of the results obtained for this same pellet material by Campos and Lima (1987).

3.3. Dose-response curve of the NIST applicator

The dosimetric system is composed by 16 $CaSO_4$:Dy pellets. All these samples were used to obtain the dose-response curve of the NIST applicator. In this case, the $CaSO_4$:Dy dosimeters were irradiated using the NIST applicator in a dose interval from 5 to 20 Gy. A null distance between dosimeter and source was utilized. The dose-response curve obtained can be seen in Fig. 1 (Antonio et al., 2010).

The TL pellets presented the expected result in the whole tested dose interval. A linear behavior was observed up 10 Gy. Afterwards, a supralinear TL response occured. From these measurements, calibration factors were obtained.

Table 1
Characteristics of the $^{90}Sr+^{90}Y$ sources calibrated in this work.

Hospital	Source	Source Number	Model	Nominal Activity (MBq)	Absorbed Dose Rate (Gy/s)	Calibration Date
1	Dermatological	1	0103 MP – SIQ18	1480	0.060 ± 0.012	25.10.78
	Ophthalmic	2	0071 ML – SIA6	370	0.055 ± 0.016	02.10.78
2	Dermatological	3[a]	–	–	0.033 ± 0.007	01.03.91
	Dermatological	4[a]	–	–	0.033 ± 0.007	01.03.91
	Ophthalmic	5[a]	–	–	0.033 ± 0.010	01.03.91
3	Dermatological	6	0371 MP – SIQ18	1480	0.062 ± 0.012	18.08.93
	Dermatological	7	0360 MP – SIQ21	740	0.070 ± 0.014	21.06.93
	Ophthalmic	8	1003 ML – SIA6	370	0.064 ± 0.019	21.06.93
	Ophthalmic	9	SIAS/1116 – SIA5	74	0.042 ± 0.013	01.02.69
4	Dermatological	10	SR 1073 – SIQ20	370	0.029 ± 0.006	15.08.73
	Ophthalmic	11	SIA6/1447	370	0.075 ± 0.022	05.06.73
5	Dermatological	12	0333 MP – SIQ21	740	0.051 ± 0.010	11.02.92
	Ophthalmic	13	SIA5/1298	74	0.036 ± 0.011	10.08.71
	Ophthalmic	14	0931 ML – SIA6	370	0.049 ± 0.015	24.01.92

[a] No present original certificate.

Table 2
Absorbed dose rates obtained of the clinical applicators of five hospitals in São Paulo.

Clinical Applicator	Absorbed Dose Rate (Gy/s)		Difference (%)
	Certificate	This work	
1	0.0279 ± 0.0056	0.0359 ± 0.0072	−22
2	0.0256 ± 0.0077	0.0335 ± 0.0101	−23
3	0.0207 ± 0.0041	0.0227 ± 0.0045	−9
4	0.0207 ± 0.0041	0.0225 ± 0.0045	−8
5	0.0207 ± 0.0062	0.0255 ± 0.0076	−19
6	0.0412 ± 0.0082	0.0648 ± 0.0130	−36
7	0.0463 ± 0.0093	0.0683 ± 0.0137	−32
8	0.0430 ± 0.0127	0.0649 ± 0.0195	−34
9	0.0155 ± 0.0046	0.0143 ± 0.0043	8
10	0.0119 ± 0.0024	0.0170 ± 0.0034	−30
11	0.0306 ± 0.0092	0.0403 ± 0.0121	−24
12	0.0325 ± 0.0065	0.0445 ± 0.0089	−27
13	0.0140 ± 0.0042	0.0129 ± 0.0034	8
14	0.0313 ± 0.0094	0.0401 ± 0.0120	−22

3.4. Calibration of the clinical applicators

The TL detectors were irradiated at the hospitals using the dosimetric system and the different clinical applicators. The irradiated TL pellets were evaluated at the Calibration Laboratory of IPEN in relation to their TL response. From the dose-response curve obtained with the NIST applicator, it was possible to determine the absorbed dose rate of each applicator. For the calibration of each source 4 to 8 pellets were exposed to radiation, depending on clinical applicator.

At the hospitals, the dosimeters were irradiated with different time intervals that varied between 180 s and 360 s, according to the source activity. During these irradiations, a null distance between source and dosimeter was also utilized. In all hospitals, one pellet was not irradiated; it was the control dosimeter. After the calibration of the applicators, calibration certificates were emitted. The absorbed dose rates obtained in this work are shown in Table 2. The maximum relative deviation in relation to the TL response was 7.7% for applicator 9.

Comparing the values of the absorbed dose rates obtained in this work with the values provided in the calibration certificates after the radioactive decay, the maximum difference was −36% for applicator 6, while the minimum differences were −8% and 8% for applicators 4 and 9, respectively.

Taking into consideration that the expanded uncertainty of the NIST applicator is 12% and that the uncertainties described in the source certificates are equal to 20% (dermatological applicators) and 30% (ophthalmic applicators), the uncertainties and the differences obtained and shown in this work can be considered acceptable. Furthermore, the differences agree with the results obtained by Soares (1995).

The uncertainties presented in the source calibration certificates are expanded uncertainties (2σ). For the calculation of the associated uncertainties of the absorbed dose rates in this work, the uncertainties of type A (statistical) and type B (instrumental) were taken into account, and the expanded uncertainties were obtained. For the determination of the total uncertainties, those associated uncertainties to the measurements, temperature, pressure and humidity instruments, and the uncertainty of each source were considered.

Conclusions

It was very useful to show the calibration steps to the clinical applicator operators, to ensure the future correct use of the dosimetric system. Furthermore, this routine procedure was a form of introducing the dosimetric system in the quality control program of the clinics.

During the visits to the clinics, the calibration procedure of the $^{90}Sr+^{90}Y$ sources was explained, and then the dosimetric system was applied. The results obtained for the dosimetric characterization of the thin $CaSO_4$:Dy pellets were satisfactory. The dosimetric system can be used by the radiotherapy clinics and hospitals in São Paulo city and later by all Brazilian clinics and hospitals, in the form of a postal dosimetric system.

Acknowledgements

The authors thank Dr. Helen J. Khoury for the Harshaw TLD Reader, model 3500, and CNPq, FAPESP, CAPES and MCT (Project INCT for Radiation Metrology in Medicine), for partial financial support.

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