Calibration of $^{90}Sr+^{90}Y$ sources used for betatherapy, using a postal kit of thermoluminescent dosimeters

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Abstract. According to international recommendations, the sources used in procedures of brachytherapy have to be calibrated in order to confirm the absorbed dose rates. In order to follow the recommendations and to collaborate for the continuous use of these sources, a dosimetric system for their calibration was developed at the Calibration Laboratory at IPEN, and it was tested in some hospitals at the São Paulo city to train the users of clinical applicators, and to answer the possible questions that may appear in relation to the calibration procedure. These situations were necessary to verify the possibility of application of this dosimetric system as a mail system, because there are hospitals and clinics in almost all Brazilian states that still use clinical applicators. To send these sources to the Calibration Laboratory is difficult, and it requires authorization from the governmental authorities. The thermoluminescent dosimeters of the mail system were already characterized. This postal kit was tested to calibrate $^{90}Sr+^{90}Y$ clinical applicators; the absorbed dose rates obtained were considered satisfactory.

Keywords: $^{90}Sr+^{90}Y$ clinical applicators, calibration, $CaSO_4$:Dy pellets, thermoluminescent dosimeters.

1. Introduction

The need of calibration of $^{90}Sr+^{90}Y$ clinical applicators, special beta particle emitting sources used in betatherapy procedures for clinical or esthetical treatments, is already known for many years, by means of reports and recommendations of several authors [1-4]. This procedure is of great importance, because these sources are very old (some are from the 60's), in addition to the necessity of the establishment of a quality control program for these sources, assuring that the sources are used correctly and the treatments of the patients will bring effective results. There sources are mainly used to treat keloids (dermatological/plane applicators) and pterigium (ophthalmic/concave applicators) problems.

There are many techniques to calibrate clinical applicators, as for example the use of extrapolation chambers [5], radiochromic films [6] and thermoluminescent dosimeters (TLD) [7]. This last method presents some advantages, as easy handling and readout, and small dimensions. Oliveira and Caldas [8] studied the application of thin $CaSO_4$:Dy dosimeters in the calibration of $^{90}Sr+^{90}Y$ clinical applicators, and concluded that this material is very efficient for the determination of the absorbed dose rates of these kinds of sources.

In some countries, the use of $^{90}Sr+^{90}Y$ clinical applicators was suspended, because they are not commercialized anymore. The use of beta sources was replaced by linear accelerators ou kilovoltage

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X-ray systems (in the case of keloids) [9]. However, the $^{90}Sr+^{90}Y$ concave and plane sources are still very utilized in Brazil, in almost all federal states, for betatherapy in the treatments of superficial lesions (kelois and pterigium).

Based on the principle of the studies [1-3,8], Antonio and Caldas [7] developed in 2011 a dosimetric system for calibration of $^{90}Sr+^{90}Y$ clinical applicators, using thin $CaSO_4$:Dy pellets produced at the Instituto de Pesquisas Energéticas e Nucleares (IPEN). They applied this system in hospitals of São Paulo city with the objective to establish a training program to the operators of these sources about how to use them, and mainly to eliminate possible doubts about their calibration. The purpose was to send this dosimetric system, in future, as a postal system to other Brazilian clinics and hospitals that use $^{90}Sr+^{90}Y$ applicators.

As the calibrations performed in the study of Antonio and Caldas [7] presented satisfactory results between the absorbed dose rates obtained and the ones provided in the calibration certificates, for different clinical applicators, the objective of this work was to verify the usefulness of this system as a postal kit, using the usual mail system. The need of the establishment of a program for this postal kit is mainly due to the fact of the transport difficulty from the clinics and hospitals to the calibration laboratories.

2. Materials and Methods

For the calibration of the $^{90}Sr+^{90}Y$ clinical applicators, thin $CaSO_4$:Dy thermoluminescent (TL) dosimeters, with dimensions of 6.0 mm of diameter and 0.2 mm of thickness, were utilized; these samples were produced at the Dosimetric Materials Laboratory of IPEN. The dosimetric system was composed by sixteen TL dosimeters, a clamp, a polymethymethacrylate (PMMA) support (with dimensions of 5.0 cm of diameter and 1.0 cm of thickness) to fix the TL pellets involved by a plastic film, with superficial density of 1.095 mg/cm^2 (for protection of the pellets during the irradiations), an aluminum support to storage the TL detectors (before irradiations), a dark small box for the TL detectors (after the irradiation procedure), two pairs of gloves, a chronometer and a pen. All components were positioned in a organizing box for the storage of the items of the system, and it may be seen in Fig. 1. Furthermore, an irradiation methodology, an irradiation procedure form, a data collection form and a revision sheet were sent together with the kit.

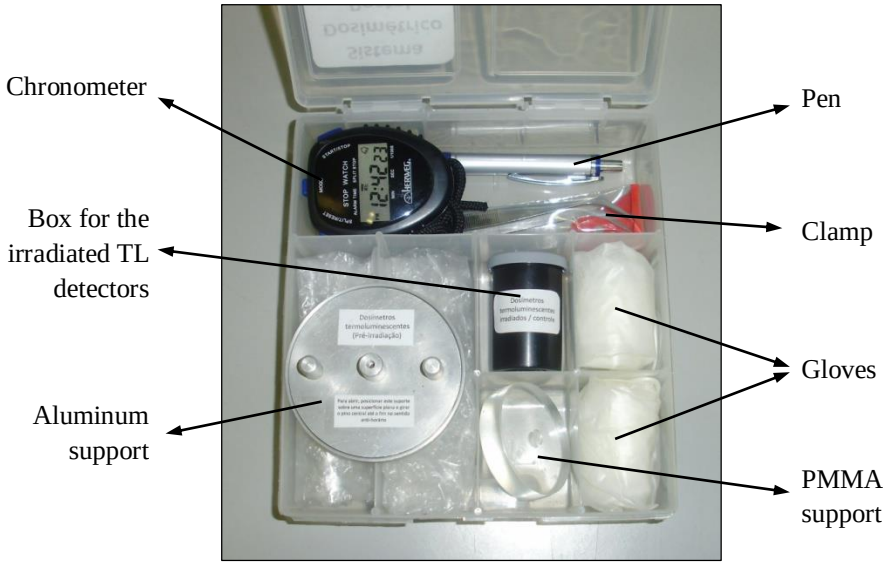

Figure 1 – Items of the dosimetric postal kit, for the calibration of $^{90}Sr+^{90}Y$ clinical applicators.

A $^{90}Sr+^{90}Y$ clinical applicator was utilized as a secondary standard system for the calibration of the other applicators, because it was calibrated at the primary standard laboratory National Institute of Standards and Technology (NIST). This applicator was called, in this work, NIST applicator. During the irradiations, the distance between each sample and source was null (in the same conditions used during the irradiations of the NIST applicator), and an adequate support to fix the source (vertically) on the pellet was utilized.

In this work, the dosimetric postal system was sent to the Federal University of Sergipe (UFS), at Aracaju city (about 2,174 km of distance from São Paulo). The TL dosimeters were irradiated following the irradiation procedure form. Three $^{90}Sr+^{90}Y$ clinical applicators, all from Amersham International, England, with calibration certificates from The Radiochemical Centre, Amersham (manufacturer certificate) were calibrated using the postal kit. The description of these sources is presented in Table 1.

Table 1 – Description of the $^{90}Sr+^{90}Y$ clinical applicators used in this work.

Source Number	Clinical Applicator	Model	Nominal Activity (MBq)	Absorbed Dose Rate (Gy/s)	Calibration Date
1	Dermatological	1520 – SIA5	74	0.018 ± 0.004	27.11.1973
2	Ophthalmic	928 – SIA6	370	0.027 ± 0.008	14.01.1992
3	Ophthalmic	1522 – SIA6	370	0.022 ± 0.017	27.11.1973

The measurements were taken after the postal system returned to IPEN, and they were analyzed using a Harshaw TLD reader model 3500, with light emission integrated in the temperature interval from 180°C to 350°C. After the measurements, the $CaSO_4$:Dy pellets were termally treated at 300°C during 3 h for posterior reutilization.

3. Results

Prior the establishment of the dosimetric system, the TL dosimeters were characterized, and these results were reported by Antonio and Caldas [7].

3.1. Development of the Dosimetric Postal Kit

As the dosimetric postal system (or postal kit) was developed to attend the necessity of the Brazilian clinics and hospitals in relation to the calibration of their $^{90}Sr+^{90}Y$ clinical applicators, it was necessary to verify the viability and the effectiveness of this system [7]. After the conclusion that this system could be used as postal system, the irradiation procedure form already utilized by Antonio and Caldas [7], was refined based in the doubts presented by the source operators during the visits to the hospitals in São Paulo city. This form contains all steps necessary to calibrate a clinical applicator, since important recommendations about the protection of the source operators and who are allowed to perform the irradiations, until the step by step procedure during the irradiations to be realized in the own place where the clinical applicators are used. Furthermore, a data collection form was also developed (to be completed by the responsible of the sources with data about the source owners, the sources, and the irradiation procedure). An item revision sheet consisting of all the items of the postal system was also sent; there is a proper place to be completed by the source operators, that must return to the LCI.

3.2. Determination of the Absorbed Dose Rates

For the calibration of the $^{90}Sr+^{90}Y$ clinical applicators of the UFS, a dose-response curve obtained for the NIST applicator [7], was utilized; it is presented in Fig. 2.

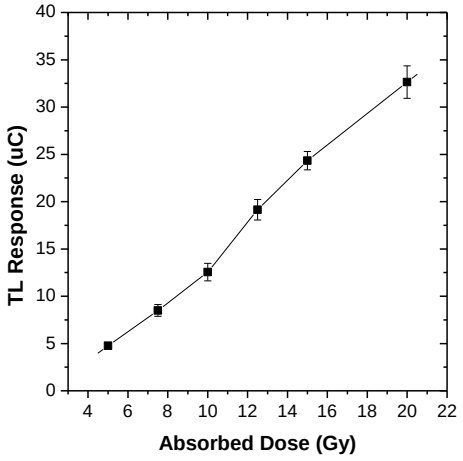

Figure 2 – Dose-response curve of the thin $CaSO_4$:Dy detectors, using the NIST reference $^{90}Sr+^{90}Y$ applicator.

From the set of sixteen $CaSO_4$:Dy pellets, four were not irradiated, and they were used as control dosimeters; four samples were irradiated using each one of the three clinical applicators during different time intervals (Table 2), which were determined and used according to the absorbed dose rates provided at the calibration certificate of each source.

The absorbed dose rate for each applicator was determined using the dose-response curve of the NIST applicator. After the irradiations made at the UFS and the evaluation of their measurements at the LCI (IPEN), a calibration certificate was emitted for each clinical applicator. The results obtained for the calibration of all three clinical applicators are shown in Table 2. The maximum relative deviation obtained in all the measurements was 8.1%, for the applicator 2.

Table 2 – Absorbed dose rates obtained for the three $^{90}Sr+^{90}Y$ clinical applicators of the UFS.

Source Number	Source	Irradiation Time (min)	Absorbed Dose Rate (Gy/s)		Difference (%)
			Certificate	This work	
1	Dermatological	10	0.0070 ± 0.0014	0.0076 ± 0.0015	-7.9
2	Ophthalmic	6	0.0167 ± 0.0050	0.0227 ± 0.0076	-26.4
3	Ophthalmic	8	0.0087 ± 0.0026	0.0189 ± 0.0059	-54.0

The values of absorbed dose rates obtained in this work were compared with the ones provided in the calibration certificate of each applicator. Applicator 1, dermatological, presented the minimum difference of -7.9%, which agrees with calibration results of other applicators [7]. The applicators 2 and 3, ophthalmic, presented high differences.

4. Conclusions

The dosimetric postal system was put into practice in this work after having been tested in a previous study. Using this system, three $^{90}Sr+^{90}Y$ clinical applicators (one dermatological and two ophthalmic) had their absorbed dose rates obtained using TL detectors of $CaSO_4$:Dy.

The result obtained in this work for the dermatological applicator demonstrated a difference between the absorbed dose rate of this work and that provided in its calibration certificate (corrected for the radioactive decay) acceptable in the point of view of other studies and the uncertainty presented in its certificate of 20%.

In relation to the ophthalmic applicators, the results of the calibration and the differences obtained between the absorbed dose rates were higher than that obtained for the dermatological applicator (-26.4% and -54.0% to the applicator 2 and 3, respectively). The first difference obtained can be considered acceptable, because it is compatible with the uncertainty presented in the calibration made by the manufacturer, that is 30%. However, the second difference (-54%) was considered a very high value, and this may be due to factors such as small errors during the irradiation

of the samples, the format of the source, or the disposal of radioactive material on the source surface, which may not be homogeneous. This clinical applicator will be calibrated again.

Acknowledgments

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