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Review

Calibration of the $^{90}Sr+^{90}Y$ ophthalmic and dermatological applicators with an extrapolation ionization minichamber

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HIGHLIGHTS

- $^{90}Sr+^{90}Y$ clinical applicators were calibrated using a mini-extrapolation chamber.
- An extrapolation curve was obtained for each applicator during its calibration.
- The results were compared with those provided by the calibration certificates.
- All results of the dermatological applicators presented lower differences than 5%.

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ABSTRACT

$^{90}Sr+^{90}Y$ clinical applicators are used for brachytherapy in Brazilian clinics even though they are not manufactured anymore. Such sources must be calibrated periodically, and one of the calibration methods in use is ionometry with extrapolation ionization chambers. $^{90}Sr+^{90}Y$ clinical applicators were calibrated using an extrapolation minichamber developed at the Calibration Laboratory at IPEN. The obtained results agree satisfactorily with the data provided in calibration certificates of the sources.

Contents

1. Introduction

Beta-emitting $^{90}Sr+^{90}Y$ clinical applicators developed by Friedell et al. (1950) have found application in treatments of superficial lesions, such as keloids and pterigiums. According to Soares (1995), in the 1990s, about 10 manufacturers were fabricating many such applicators, which were used worldwide.

The clinical applicators must be periodically calibrated according to international recommendations (IAEA (International Atomic Energy Agency), 2002; ICRU (International Commission on Radiation Units and Measurements), 2004). One of the calibration methods currently in use is based on measurements with extrapolation ionization chambers (Soares et al., 2001; Holmes et al., 2009). These devices are plane-parallel ionization chambers with

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Table 1
Characteristics of the calibrated ^{90}Sr+^{90}Y clinical applicators.

Applicator	Type	Manufacturer and model	Absorbed dose rate (Gy/s)	Calibration date
A	Dermatological	*Amersham* SIQ 18	0.056 ± 0.011	08.11.1968
B	Dermatological		No certificate	
C	Dermatological	*Amersham* SIQ 21	0.053[a]	17.09.1986
D	Dermatological	*Amersham* 5072 2096	0.04[a]	14.05.2003
E	Dermatological and ophthalmic	*Amersham* SAI 20	0.438[a]	31.07.1996
F	Ophthalmic	*Amersham* SAI 6/1418	0.03[a]	14.05.2003

[a] No information on the uncertainties in the calibration certificates.

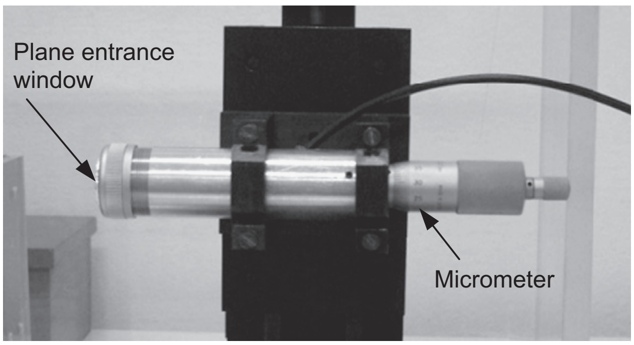

Fig. 1. Extrapolation ionization minichamber used in this work held by the support.

adjustable sensitive volume. They are also used in measurements of surface doses because they allow for extrapolating the ionization current to zero distance between the electrodes (Böhm and Schneider, 1986; Oliveira and Caldas, 2005).

An alternative method to calibrate the applicators is thermoluminescence, which can be easily used directly in the clinics in the absence of extrapolation ionization chambers. In particular, a study of $CaSO_4$:Dy has demonstrated that this material can be effectively used in measurements of doses from the ^{90}Sr+^{90}Y clinical applicators (Oliveira and Caldas, 2007; Antonio and Caldas, 2011).

In this work, an extrapolation minichamber with a planar window developed at the Calibration Laboratory (LCI) of IPEN by Oliveira and Caldas (2005) was used. The design of the chamber is adequate for calibration of the clinical applicators. The aim of this work was to perform absolute calibrations of some dermatological and ophthalmic applicators with this chamber.

2. Materials and methods

Six ^{90}Sr+^{90}Y clinical applicators were used. Four of them were planar dermatological (further referred to as A–D); another one, slightly curved, was used as both a dermatological and an ophthalmic applicator (further referred to as E); and yet another one, curved, was an ophthalmic applicator (further referred to as F).

Applicators A and C–F were manufactured and calibrated by Amersham, while Applicator B had no certificate. Applicators A and B were received from LCI, and the others were kindly provided by clinics. Table 1 lists the main characteristics of the tested applicators.

The chamber was used in tandem with a PTW Unidos electrometer (Model 10475). The chamber had an aluminum body, an entrance window made of doubly aluminized polyester foil with area density $(111.4 \pm 2.6) \times 10^{-5}$ g cm^{-2}, and a micrometer screw, which allowed for variations of the distance between the collecting electrode and the entrance window from 0 to 25 mm (Oliveira and Caldas, 2005). Ionization currents were measured, and the readings were corrected for the variations in the atmospheric pressure, temperature, and air humidity. In the calibrations of the clinical applicators, the chamber and each source were positioned horizontally on a special support designed for this procedure. Fig. 1 shows the chamber, while Fig. 2 displays the setup.

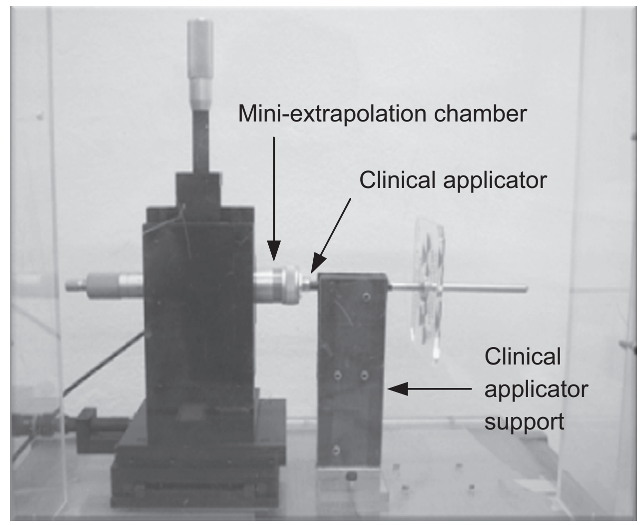

Fig. 2. Setup for calibration of the ^{90}Sr+^{90}Y clinical applicators with the extrapolation ionization minichamber.

The uncertainties of all measurements were analyzed and expressed according to the recommendations of the Brazilian Association of Technical Standards (ABNT, 2003). The standard uncertainties were classified into Type A and Type B categories, and the expanded uncertainties were then calculated. As an example, Table 2 shows details of the uncertainty calculations for Applicator A.

3. Results

A calibration of the clinical applicators with the extrapolation chamber without another radiation source used as a reference is based on the following equation (Oliveira and Caldas, 2005):

$$\dot{D}_{water} = \frac{(W/e).S_{air}^{water}}{\rho_0.a}.(\Delta I/\Delta d)_{d \to 0}.k_{back} \quad (1)$$

where W/e is the average air ionization energy (33.83 ± 0.068) J C^{-1}; S_{air}^{water} is the ratio of the mean collision stopping powers of water to air (1.124 ± 0.007); ρ_0 is the air density at normal pressure and temperature (1.197 ± 0.001) kg/m^3; a is the effective area of the collecting electrode of the extrapolation minichamber, 1.68 mm^2; $(\Delta I/\Delta d)_{d \to 0}$ is the slope of the curve of the dependence of the chamber ionization current on the distance between the chamber electrodes in the range of the distance extrapolation to zero; and k_{back} is the correction factor that takes into account the difference in backscattering between the collecting electrode and water, 1.01006.

Initially, the extrapolation curve was obtained for each clinical applicator to get the angular coefficient $(\Delta I/\Delta d)_{d \to 0}$.

Table 2
Uncertainty budget for the determined dose rate to water for Applicator A (the quoted values, with the exception of the final result, represent single standard deviations and uncertainties).

Uncertainty	Components		Uncertainty (%)
Standard	Type A	Current measurements	1.000
	Type B	Thermometer	0.230
		Barometer	0.001
		Hygrometer	1.250
		Electrometer	0.032
		Clinical applicator	10.00
Combined	Angular coefficient *B*		10.13 (standard uncertainties)
	Average air ionization energy W/e		0.200
	Ratio of the mean collision stopping powers of water and air S_{air}^{water}		0.620
	Air density ρ_0		0.080
Expanded combined uncertainty, $k=2$			**20.30**

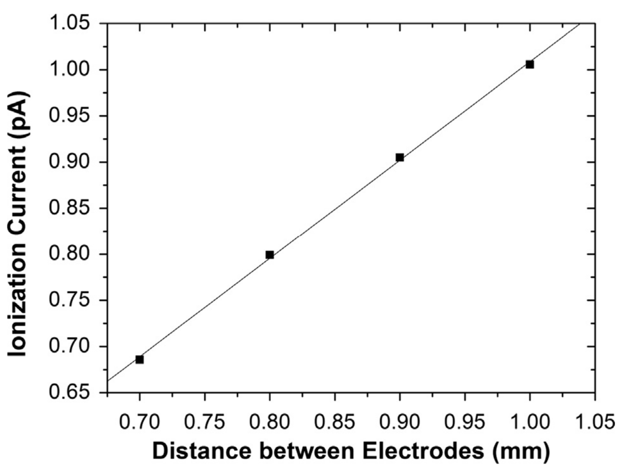

Fig. 3. A representative extrapolation curve obtained with the minichamber for the dermatological Applicator A.

Table 3
Comparison of the absorbed dose rates quoted in the applicator calibration certificates and found in this work.

Applicator	Absorbed dose rate (Gy/s)		Difference (%)
	Certificate	This work	
A	0.0213 ± 0.0043	0.0203 ± 0.0041	+4.9
B	No certificate	0.0227 ± 0.0046	–
C	0.0299	0.0308 ± 0.0062	−2.9
D	0.0349	0.0353 ± 0.0072	−1.1
E	0.3245	0.3288 ± 0.0988	−1.3

In the extrapolation curve measurements, the distance between the electrodes was varied between 0.7 and 1.0 mm to avoid a deformation of the entrance window, which may occur at distances shorter than 0.40 mm (Oliveira, 2005). The source under calibration was in contact with the entrance window of the chamber.

For each interelectrode distance, five electric charge readings were taken at each polarity; the charge collection time in each measurement was 60 s. The bias was ±50 V in all measurements. The extrapolation curves for all the applicators were linear with linear correlation coefficients above 0.9995. Fig. 3 shows the extrapolation curve for Applicator A as an example.

The absorbed dose rates to water were found from the determined angular coefficients using Eq. (1) (Table 3). They were compared with the corresponding values quoted in the calibration certificates after a proper correction for the decay. The agreement was generally very good. For Applicator F, however, the discrepancy was 23.6%, which can be attributed to the poor contact between the concave surface of this ophthalmic applicator and the flat surface of the chamber window.

4. Conclusions

In this work, six $^{90}Sr+^{90}Y$ clinical applicators were calibrated using an extrapolation minichamber with a plane entrance window. The results were compared with those provided in the calibration certificate for each source. The minimal discrepancy was −1.1% for Applicator D, while the maximal discrepancy was +23.6% for Applicator F. The uncertainties of calibration of the dermatological applicators from Amersham quoted in the certificates were typically ±20% (Amersham, 1968, 1986), while the uncertainties of the reported values for the ophthalmic applicators usually were ±30% (Amersham, 1996). So, the calibrated extrapolation minichamber can be effectively used as a tool for absolute calibrations of $^{90}Sr+^{90}Y$ clinical applicators.

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