Proficiency test for calibration of well-type chambers using two types of ^{192}Ir sources

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Abstract
The Secondary Standard Dosimetry Laboratory of Cuba has implemented the calibration methodology of well-type chambers using the high dose rate ^{192}Ir sources. The use of different source types, at the hospital site as a modification of the procedure using other source types in a permanent facility of the primary laboratory leads to the need to evaluate the performance of the secondary procedure for calibration. The present paper describes the proficiency test to Cuban laboratory by making a comparison of dosimetry standards used in Germany and Cuba.

Key words: *brachytherapy, iridium 192, sealed sources, calibration, dosimetry, interlaboratory comparisons*

Ensayo de aptitud para calibrar cámaras de pozo usando dos tipos de fuentes de ^{192}Ir

Resumen
El Laboratorio Secundario de Calibración Dosimétrica de Cuba ha implementado una metodología para calibrar cámaras de pozo utilizando fuentes de ^{192} Ir de altas tasas de dosis. El uso de diferentes tipos de fuentes, como parte de una modificación del procedimiento con otro tipo de fuente usada en una instalación permanente del laboratorio primario, provocó la necesidad de evaluar el desempeño del procedimiento secundario de calibración. El trabajo describe el ensayo de aptitud al laboratorio cubano mediante un ejercicio de comparación entre los patrones dosimétricos de Alemania y Cuba.

Palabras clave: *braquiterapia, iridio 192, fuentes encapsuladas, calibración, dosimetría, comparaciones interlaboratorios*

Introduction

There are two calibration techniques commonly accepted for the calibration of brachytherapy photon sources. One of them is the calibration using free in air measurements and another is based on use of the well-type ionization chamber. Both of these methods are recommended in the technical document published by the International Atomic Energy Agency (IAEA) [1].

For the Cuban Secondary Standard Dosimetry Laboratory (SSDL) the preferred method for source calibrations is to have the well-type chamber calibrated against the primary standard at the National Metrology Institute. Because there is no high dose rate afterloader at the SSDL, the calibration of the client source can be done only in a hospital set-up using the calibrated well-type chamber from SSDL. Afterwards this step, the chamber of the client is calibrated using the calibrated source. Although this last method has the advantage that the measurement set-up is simplified but problems may arise from the use of different source designs during calibration of the secondary standard at the primary laboratory and during calibration of the chambers of client at the hospital set-up. The use of different sources may result in variations in the response of the chamber either related to design or to source-source manufacturing variations. The variations due to the design are a consequence of the effects of source geometry, encapsulation, cable and self-absorption within the source. In addition, the use of different adapters can lead to some variations too. The deviation of the calibration coefficient of the PTW 33004 chamber due to the use of some source types and adapters has been experimentally measured [2]. The larger differences can be near 4 % being unsuitable for the accuracy requirements of the dosimetry calibrations for Brachytherapy.

All those facts reinforced the idea to conduct a proficiency test to demonstrate that the calibration procedure used by SSDL can be applied in practice and will not lead to the incorrect calibration coefficient within the stated uncertainty. The present paper describes the comparison exercise between German and Cuban standards using High Dose Rate (HDR) ^{192}Ir sources in terms of Reference Air Kerma Rate. The comparison was conducted to confirm whether acceptable performance had been achieved by the Cuban laboratory, for the calibration capability.

Material and Methods

Calibration of secondary standard at the primary laboratory

The Cuban secondary standard is composed of the PTW 33004 s/n 00154 well-type chamber and the UNIDOS Webline s/n 0023 electrometer. The secondary standard was calibrated at the German Metrology Institute (Physikalisch-Technische Bundesanstalt - PTB) for HDR ^{192}Ir source in terms of Reference Air Kerma Rate. First, the GAMMAMED HDR 12i type source was calibrated by the free in air technique using the collimated beam to reduce the scattered radiation component at the points of measurements. The LS-01 standard chamber was positioned at 1.0 m from the source on the central axis of the radiation field with the aid of an industrial robot. The air kerma rate was determined by using of the calibration coefficient of the LS-01 chamber. Afterwards, the calibrated source was inserted inside the PTW 33004 well-type chamber, using the T33002.1.009 adapter. The calibration coefficient was determined with a standard uncertainty of 1.25 % (k = 1).

Measurement conditions

The proficiency test was developed at the routine calibration set-up of both laboratories. In the case of the Cuban SSDL the measurements were conducted in a hospital set-up. The HDR 1000 plus n/s A973052 and Nucleotron 077092 n/s 00046 well-type chambers were used as transfer instruments. Each laboratory determined the calibration coefficients of the transfer chambers.

The measurements in Cuba were conducted at the treatment room of the National Institute for Oncology and Radiobiology (INOR). The ambient conditions were at temperatures from 18 to 20 °C and atmospheric pressures from 1002 to 1012 mbar. The ^{192}Ir source was positioned inside the well-type chamber at distances from the floor and walls greater than 1.5 m. The source used was MICROSELECTRON V2, which is different from the design of the GAMMAMED HDR 12i type source used at the primary laboratory. The characteristics of each design are shown in Table 1. The main differences deal with the thickness and outer diameter of the encapsulation and cable.

In addition, two adapters were used for measurements of the chambers. In the case of the PTW 33004 and Nucleotron chambers the T33002.1.009 adapter was inserted and connected directly to the transfer tube of MICROSELECTRON and GAMMAMED afterloaders. A 70010 model adapter was used for the HDR 1000 plus chamber during the measurements with two types of sources.

The use of the same adapter for each chamber type at both laboratories was considered an important element for maintaining the accuracy of the results. Table 2 shows the possible deviation of the calibration coefficient that may be found when the last element is not considered. The table summarizes the results of testing of the PTW33004 chamber compared to the use of different adapters and sources taken from the manufacturer's report [2]. The use of the MICROSELECTRON source with T33002.1.009 adapter and the GAMMAMED source with T33004.1.013 adapter causes a 3.7 % deviation in the calibration coefficient of the chamber. The similar test using the same adapter was not done by manufacturer. On the other hand, the use of the GAMMAMED source with T33004.1.013 adapter and BEBIG Multisource with the same adapter causes only a 0.3 % deviation in the calibration coefficient. Those findings encouraged authors to run the proficiency test.

Stability checks of transfer chambers

Because of the need to transport the transfer chambers to Germany and back to Cuba, it was necessary to evaluate its stability before and after this transportation. For stability checks, the CDCSJ5 ^{137}Cs source for the HDR 1000 plus chamber was utilized. For the Nucleotron 077092, the measurements in the ^{60}Co beam were

Table 1. Characteristics of HDR ^{192}Ir sources utilized for calibrations of the chambers at the CPHR and the PTB laboratory

Source type	Active core			Encapsulation				Cable
	Material	Length (cm)	Diameter (cm)	Material	Thickness (cm)	Outer Diameter (cm)	Length (cm)	Outer Diameter (cm)
Micro Selectron V2	^{192}Ir	0.36	0.065	Stainless Steel AISI316	0.0125	0.090	0.45	0.070
Gamma Med HDR 12i	^{192}Ir	0.35	0.060	Stainless Steel AISI316L	0.0200	0.110	0.50	0.110

Table 2. Variation of calibration coefficient of PTW33004 chamber using different adapter and source types

Adapter \ Source	MicroSelectron	GammaMed	BEBIG Multisource	Varian Varisource
	Calibration Coefficient ($Gy \cdot h^{-1} \cdot A^{-1}$)			
T33002.1.009	$9.301 \cdot 10^5$	--	--	--
T33004.1.013	--	$9.663 \cdot 10^5$	$9.631 \cdot 10^5$	--
T33004.1.012	--	--	--	$9.480 \cdot 10^5$

used at 200 cm distance from the source. The reading from the source corrected for temperature and pressure and for decay of the source should remain within ± 0.5 % of the average [1]. The deviation from the average of readings was found to be 0.24 % for the Nucleotron chamber and 0.17 % for the HDR 1000 plus. It was concluded that both chambers were kept stable during the testing measurements.

Calibration point of well-type chambers

The calibration point is determined as the position of the source with the maximum response of the chamber. It was expected that this point would not differ from one source to another used in the measurements, because the source length of active core and encapsulation are very similar (see Table 1). Measurements were performed at different positions of the sources along the axis of the chambers by using the after-loading mechanism. For the secondary standard chamber the calibration point was located at 48 mm in the German laboratory and at 47.5 mm in the Cuban laboratory. The difference was derived from the use of different steps in shifting the source for determination of the calibration point, PTB used 2.0 mm and the Cuban laboratory used 2.5 mm. In the analyzing of the axial response function of the chamber it can be noted that a shift of the calibration point by 0.5 mm causes only a negligible difference in the response of the chamber. The calibration points determined for transfer chambers were similar located by both laboratories.

Results and Discussion

Both laboratories had previously agreed to evaluate the significance of the observed deviations by means of the number En recommended by ISO/IEC 17043 [3]. The number E_n considers that the results are satisfactory when $E_n \leq 1$ and unsatisfactory when $E_n > 1$. This number En combines the influence of the difference between the values of the calibration coefficient N_k reported by laboratories and its uncertainties. This number is calculated as follows:

$$E_n = \frac{N_{K,CPHR} - N_{K,PTB}}{\sqrt{u_{K,CPHR}^2 + u_{K,PTB}^2}} \tag{1}$$

where:

$N_{K,PTB}$ = calibration coefficient reported by PTB
$N_{K,CPHR}$ = calibration coefficient reported by CPHR
$u_{K,PTB}$ = global uncertainty reported by PTB at 95 % of confidence level.
$u_{K,CPHR}$ = global uncertainty reported by CPHR at 95 % of confidence level.

Calculation of calibration coefficient

The Reference Air Kerma Rate calibration coefficient of the transfer chamber, N_{KR}, is determined according to international recommendations [1] and is expressed as:

$$N_{K_R} = \frac{K_R}{M \cdot k_{tp} \cdot k_{recom} \cdot k_e} \tag{2}$$

where:

K_R is the Reference Air Kerma Rate of the source,
M is the scale unit reading,
k_{tp} is the correction factor for air density, referen ced to a temperature of 20 °C and pressure of 1013.25 mbar,
k_{recom} is the correction factor for recombination losses determined by the two voltage tech nique at the SSDL and by variation of voltage supply at the PSDL,
k_e is the electrometer correction factor.

Evaluation of uncertainties

The uncertainty of the calibration coefficients was determined according to the GUM JCGM 100 [4]. Table 3 shows the summary of the uncertainty evaluation. Type A, type B and combined standard uncertainty, U_{Nk}, are reported. The uncertainty budget of PTB is taken from the well-established procedure of the primary laboratory. The type B uncertainty of CPHR excludes the uncertainty of the calibration coefficient determined at PTB because of the correlation with the coefficient determi-

Tabla 3. Summary of the uncertainties evaluation. All figures are given in percent

Radiation quality	PTB			CPHR		
	Type A	Type B	Unk (k = 1)	Type A	Type B	Unk (k = 1)
^{192}Ir	0.50	1.15	1.25	0.01	0.47	0.47

ned at CPHR. The uncertainty of the long term stability of the secondary standard and electrometer calibration are estimated to be 0.29 % and 0.14 % respectively, and are taken from research carried out for several years in CPHR. Another influence element of uncertainty at the CPHR set-up is related to the use of different source types. From Table 2 it can be noticed that the use of different sources with the same adapter caused a change in calibration coefficient of 0.3 %. Considering that those differences can be slightly higher for the combination of the present comparison, it was estimated 0.5 % as the maximum deviation. Then it was considered as a type B uncertainty with the rectangular distribution and the maximum deviation was divided by √3. The uncertainty for using of different sources is 0.29 %. The rest of the components were estimated to be 0.1 % or less. The combined standard uncertainty, $U_N k$, of PTB and CPHR in the comparison were obtained of 1.25 % and 0.47 % respectively. To obtain the global uncertainty each combined uncertainty should be multiplied by a coverage factor of 2.

Proficiency test results

The calibration coefficients were determined at both laboratories and compared with the use of number E_n calculated by the equation (1). The results were satisfactory as number En remains below 1 (see Table 4). The differences between coefficients determined by the laboratories in the range of 0.7 to 36 mGy/h were less than 1 %.

Tabla 4. Results of proficiency test for air kerma rate calibration coefficients obtained at CPHR and PTB using the HDR ^{192}Ir source

Calibration quantity	Radiation quality	Calibrated chamber	Calibration coefficients obtained [Gy/Ah] x 10^5		En
			PTB	CPHR	
Reference Air Kerma Rate	^{192}Ir	HDR 1000 plus s/n A973052	4.67	4.65	0.16
	^{192}Ir	Nucleotron s/n 077092	8.99	9.07	0.33

Conclusions

The interlaboratory comparison between the German primary standard and Cuban secondary standard for Brachytherapy was successfully conducted. The comparison was applied as a proficiency test of metrology capability in the Cuban laboratory for calibration of well-type chambers as used in the determination of the Reference Air Kerma Rate from the HDR ^{192}Ir sources. The secondary method is different because different source type is used at the non-permanent facility. However, the testing results confirm that the implemented method has led to comparable results and the calibration procedure is acceptable for dissemination of the quantity to the users. The results of this report apply only to GAMMAMED HDR 12i and MICROSELECTRON V2 ^{192}Ir sources in a wide range of air kerma rate. It seems to have an extended application for other types of sources if the same adapter is used with the chamber. The differences of the calibration coefficients determined by both laboratories are less than 1 % and the expanded uncertainties remain less than 3 %. In this sense, it can be concluded that the acceptable performance was achieved by the Cuban laboratory and it met the suitable requirements for dosimetry in Brachytherapy.

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