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Comparative measurements in dose calibrators and a gamma-ray spectrometer

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A B S T R A C T

Specific activity results of ^{51}Cr, ^{67}Ga, ^{99m}Tc and ^{201}Tl radioactive solutions, measured in different dose calibrators located at nuclear medicine services and in a calibrated HPGe gamma spectrometer, were compared. The HPGe spectrometer was calibrated in a well defined geometry by means of ^{60}Co, ^{133}Ba, ^{152}Eu, ^{166m}Ho and ^{241}Am sources, previously standardized in a $4\pi\beta-\gamma$ coincidence system. Despite the observed differences, the results may be accepted within the 10% uncertainty range, established by Brazilian regulatory standards.

1. Introduction

Radionuclide calibrators consist of a re-entrant ionization chamber coupled to a digital electronic system, which gives a direct reading in unit of activity for the radionuclide in analysis, by means of calibration factors previously established by the manufactor for that radionuclide.

This kind of ionization chambers, also called dose calibrators or activimeters, are used in nuclear medicine services to measure the activity of radionuclides for diagnosis and therapy purposes. The quality of measurements carried out in these procedures is important because the response of the calibrators can be directly related to doses given to patients and to the quality of this kind of application.

A comparison of responses from different dose calibrators for selected radionuclides, namely ^{51}Cr, ^{67}Ga, ^{99m}Tc and ^{201}Tl is presented here, as well as the measurements of the same solutions made in a gamma-ray spectrometer. The measurements obtained from all dose calibrators used in this paper were compared with the gamma spectrometer results.

The radioactive solutions were supplied by the Radiopharmaceutical Center of the Nuclear and Energy Research Institute, IPEN, from São Paulo, which is the largest radionuclide supplier to nuclear medicine services in Brazil.

The selected dose calibrators were six commercial models from Capintec Inc., one from Victoreen Inc., and two NPL-CRC secondary standards. The gamma spectrometer was HPGe germanium, calibrated in a well-defined geometry by means of standard radioactive sources.

2. Experimental method

2.1. Sample preparation

The sources for dose calibrators were prepared by pouring 4 mL from the stock solution into borosilicate 20 mL vials manufactured by Schott Inc. These vials are generally used by the IPEN Radiopharmaceutical Production Center and distributed to medicine services.

The sources to be measured in the HPGe spectrometer system were prepared by dropping aliquots from the stock solution onto Collodion film substrate.

The masses of both kinds of sources were determined by the pycnometer technique (Campion, 1975) using a Sartorius MC 21S balance.

2.2. Gamma-ray spectrometer

The gamma-ray spectrometer system includes a detector type REGe with 500 μg thick beryllium window, calibrated in a defined geometry in the range of 59–1408 keV using ^{60}Co, ^{133}Ba, ^{152}Eu, ^{166m}Ho and ^{241}Am sources, previously standardized in a $4\pi\beta-\gamma$ primary system (Moreira et al., 2008).

The source-detector distance used was around 17.9 cm, in order to reduce coincidence sum effects. The dead time and pile up corrections were applied by the pulser method (Debertin and Helmer, 1988). For these corrections, a 60 Hz pulser was connected in the pre-amplifier line. The pulser peak was adjusted to appear at the end of the multichannel spectrum, out of the energy region considered.

The source activities were determined to analyze the total absorption peak of the most intense gamma-ray. The analyses of

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spectra were carried out by means of Alpino code (Dias, 2001), which applies the method of simple integration on the total absorption peak after the background subtraction.

2.3. Dose calibrators measurements

The measurements in the dose calibrators were performed by six readings of the activity and subtracting the zero offset, after the background had been automatically subtracted. This procedure was done three times for each solution. The final activity was the average of these measurements; the uncertainty considered was the standard deviation. The identification codes and models of the dose calibrators used in this work are presented in Table 1.

3. Results

The activity values with statistical uncertainty type A, $k=2$, for ^{51}Cr, ^{67}Ga, ^{99m}Tc and ^{201}Tl are presented in Table 2. Table 3 shows the values of dose calibrator readings related to the average value from two NPL-CRC® reference dose calibrators. The maximum deviation with respect to reference was 3.7% for ^{67}Ga and ^{99m}Tc, 2.5% for ^{51}Cr and 5.2% for ^{201}Tl. The specific activities measured in the HPGe spectrometer are presented in Table 4. These results are the weighted averages from six sources for each radionuclide.

Table 1
Identification code of dose calibrators.

Identification code	Dose calibrator model
A	Capintec CRC-15R
B	Capintec CRC-15R
C	Capintec CRC-15R
D	Capintec CRC-15R remote interface
E	Capintec CRC-35R
F	Capintec CRC-35R
G	Victoreen Deluxe isotope II
H	NPL-CRC® 13
I	NPL-CRC® 15

Table 2
Activity values of ^{51}Cr, ^{67}Ga, ^{99m}Tc and ^{201}Tl.

Code	^{51}Cr Activity (MBq)	^{67}Ga Activity (MBq)	^{99m}Tc Activity (MBq)	^{201}Tl Activity (MBq)
A	–	132.61(3)	1075(2)	80.63(19)
B	–	132.66(13)	1078(1)	80.40(5)
C	45.48(4)	134.04(5)	1089(2)	81.41(2)
D	45.00(3)	132.01(3)	1073(2)	79.88(3)
E	45.78(18)	133.25(24)	1080(1)	80.89(3)
F	45.53(18)	132.57(13)	1074(2)	80.63(21)
G	–	131.89(55)	1088(5)	80.97(8)
H	44.58(11)	137.22(19)	1119(2)	83.86(13)
I	44.23(26)	136.46(30)	1106(2)	84.17(47)

Table 3
Ratio of dose calibrator activity to NPL average activity.

Radionuclide	^{51}Cr	^{67}Ga	^{99m}Tc	^{201}Tl
Average NPL (MBq)	44.41(25)	136.84(54)	1113(9)	84.02(22)
Dose calibrator	Ratio	Ratio	Ratio	Ratio
A	–	0.969(4)	0.967(8)	0.960(3)
B	–	0.969(4)	0.969(8)	0.957(3)
C	1.024(6)	0.980(4)	0.978(8)	0.969(3)
D	1.013(6)	0.965(4)	0.965(8)	0.951(3)
E	1.031(6)	0.974(4)	0.971(8)	0.963(3)
F	1.025(7)	0.969(4)	0.965(8)	0.960(4)
G	–	0.964(4)	0.978(9)	0.964(3)

Table 4
Specific activity values of ^{51}Cr, ^{67}Ga, ^{99m}Tc and ^{201}Tl, measured in the HPGe system.

Radionuclide	Activity (MBq/g)
^{51}Cr	10.02 ± 0.07
^{67}Ga	34.11 ± 0.26
^{99m}Tc	252.7 ± 3.0
^{201}Tl	19.78 ± 0.18

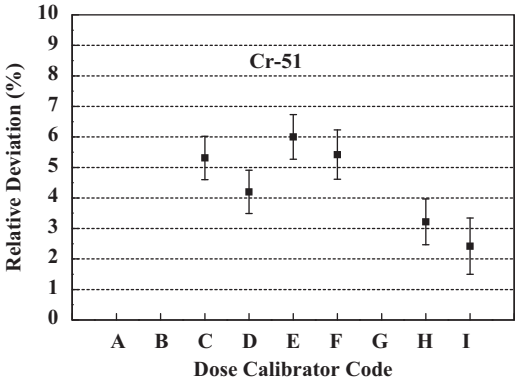

Fig. 1. Relative deviation in percentage related to the dose calibrator specific activity to the HPGe for ^{51}Cr.

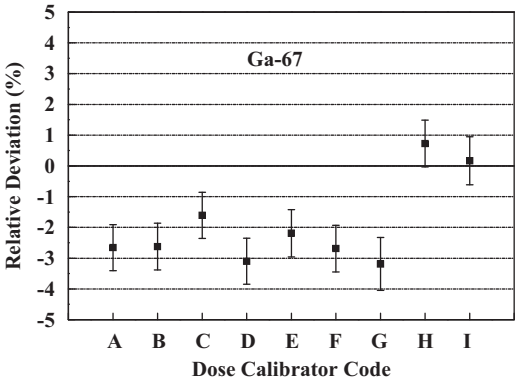

Fig. 2. Relative deviation in percentage related to the dose calibrator specific activity to the HPGe for ^{67}Ga.

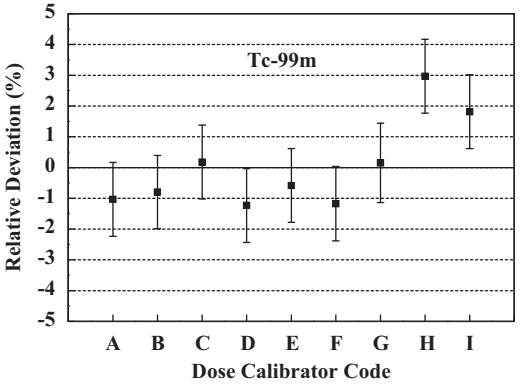

Fig. 3. Relative deviation in percentage related to the dose calibrator specific activity to the HPGe for ^{99m}Tc.

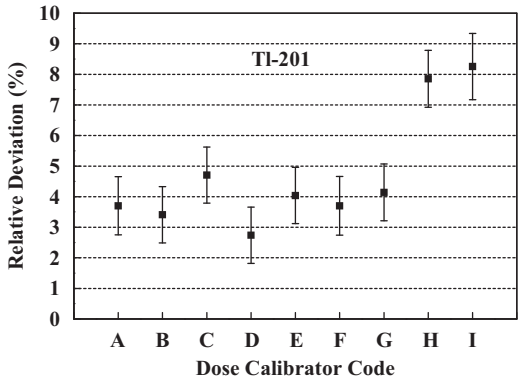

Fig. 4. Relative deviation in percentage related to the dose calibrator specific activity to the HPGe for ^{201}Tl.

The relative deviation in percentage between the calibrators specific activity and the HPGe value is presented in Figs. 1–4. The calibrators specific activity was obtained by using the solution mass determined by the pycnometer technique as described in Section 2.1. The ^{67}Ga and ^{99m}Tc results show a maximum spread of 3% related to the HPGe values. For ^{51}Cr, the spread is around 6% and for ^{201}Tl there is a spread of 8%.

4. Conclusion

The comparison of the dose calibrators to the reference NPL-CRC® systems shows that the dose calibrators tested are reliable for routine measurements, since these variations are accepted by the Brazilian regulatory standard, which is 10%.

Concerning the comparison to the HPGe values, it can be noted that there is a better agreement with NPL calibrator responses and the Capintec calibrator responses.

The differences observed for ^{51}Cr and ^{201}Tl can be attributed to the influence of low energy X-ray emission, which is more sensitive to container thickness, therefore this influence has to be investigated. The better agreement for ^{99m}Tc and ^{67}Ga can be explained by the higher values of the gamma energy for these radionuclides, namely: 140 and 300 keV, respectively, which is less dependent on the container thickness.

As it is well known, the dose calibrators are dependent on the calibrator factor established by the factory and strongly on the type of container (Schrader, 1997). The results presented in this paper suggest that a correction factor has to be applied to correct the differences between vials used in ordinary measurements and those used by the manufacturer in order to determine the ionization chambers calibrator factors.

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