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Comparison of the activity measurements in nuclear medicine services in the Brazilian northeast region

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HIGHLIGHTS

- Establishing a comparison program of activity measurements was an important tool to guarantee the satisfactory performance of radionuclide calibrators in the Brazilian northeast region.
- In this program 121 measurements performed in the nuclear medicine services of Alagoas, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe States were obtained.
- The analysis of the results demonstrated that 90% of the results received from participants are within the ±10% limit established by the Brazilian Norm.
- The services whose results were outside the recommended limits can be supported the Reference Laboratory in order to identify and to correct eventual unacceptable results.

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ABSTRACT

The Northeastern Regional Centre for Nuclear Sciences (CRCN-NE), National Nuclear Energy Commission, has organized for the first time in nuclear medicine services (NMSs) in the Brazilian northeast region a comparison of activity measurements for ^{99m}Tc, ^{131}I, ^{67}Ga, ^{201}Tl and ^{57}Co. This tool is widely utilized to evaluate not only the accuracy of radionuclide calibrators, but also the competence of NMSs to measure the activity of the radiopharmaceuticals and the performance of the personnel involved in these measurements. The comparison results showed that 90% of the results received from participants are within the ±10% limit established by the Brazilian Norm.

1. Introduction

Nuclear medicine is a field of medical imaging that involves the use of radionuclides for diagnostic or therapeutic purposes and differs from other imaging modalities because it shows the physiological processes of the system under investigation. In nuclear medicine, it is necessary to ascertain accurately the presence, the type, the intensity and the energy of the radiations emitted by the radionuclide prior to the administration to the patient (Saha, 2010). Accurate dosimetry for each specific investigation is needed in order to ensure confidence in the diagnosis or the treatment efficiency without submitting patients to unnecessary radiation exposures (Mattsson et al., 1998).

The equipment utilized in Nuclear Medicine Services (NMSs) to measure the activity of radionuclides is the radionuclide calibrator. Incorrect performance of this equipment could lead to errors in the estimation of the activity, leading to incorrect clinical interpretations, ineffective treatments and unnecessary exposure to radiation (Iwahara, 2001).

Several guides and protocols from international and Brazilian organizations summarize the recommended tests for the quality control of radionuclide calibrators. These tests include accuracy, precision, check source response, linearity and geometry. These guides recommend acceptance limits for the results of these tests (Table 1). The International Atomic Energy Agency (2006), for example, recommends an acceptance limit of ±2% when it refers to accuracy of measurement in radionuclide calibrators to

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Table 1
Acceptance limits for performance of radionuclide calibrators recommended by the international and Brazilian guides.

	CNEN	IAEA	LNHB[c]	NPL
Accuracy (%)	10	±2[a]/±5[b]	5	±2[a]/±5[b]
Precision (%)	5	1	0.2	±0.5[a]/±1[b]
Check source (%)	5	±2	1	5
Linearity (%)	20	±2[a]/±5[b]	5	±1[a]/±5[b]
Geometry (%)	Ns	>5[b]	Ns	Ns

Ns: non-specified.

[a] Secondary Standard Radioactivity Laboratory (SSRL).
[b] Nuclear Medicine Service (NMS).
[c] Laboratoire National Henri Becquerel (LNHB, 2006).

Table 2
Technical specification of the radionuclide calibrator (SRC) used in this study.

Model	CAPINTEC-CRC 15R
Type	Well-type ionization chamber
Gas	Argon
Well dimensions (cm)	6.1 × 25.4
Shielding (mm lead)	3.2
Maximum activity (^{99m}Tc)	240 GBq (6.5 Ci)
Photon energy range	25 keV to 3 MeV
Resolution	0.001 MBq (0.01 μCi)
Linearity	Within ±2%
Manufacturer's reference calibration geometry	Ampoule with 5 ml of radioactive solution
Manufacturer's calibration factors (^{99m}Tc)	080

Secondary Standard Radioactivity Laboratories (SSRLs) and ±5% to other laboratories. In Brazil, the National Nuclear Energy Commission, through the standard CNEN-NN-3.05, established that the correct value of the radiopharmaceuticals activity measurements for NMSs should be known with to within ±10% (CNEN, 1996).

Another important tool to guarantee the quality of activity measurements is the participation in comparison programs because it evaluates not only the equipment but also the technical procedures employed and the performance of the personnel engaged in the measurements (Oropesa et al., 2005, 2008). According to Oropesa et al. (2008), the improvement process comprised two phases. The first addressed the improvement in the accuracy of the calibration of the device. The second phase sought the improvement of the measurement procedures and the suitable training of personnel. Moreover, audits were organized at regular intervals, to verify the implementation of the established protocols by the Reference Laboratory.

Since 1998, the National Laboratory for Ionizing Radiation Metrology (LNMRI) of the Radiation Protection and Dosimetry Institute (IRD) has been conducting comparison programs with Brazilian NMSs in order to check the performance of their radionuclide calibrators (Iwahara et al., 2001, 2002; dos Santos et al., 2004; Alabarse et al., 2008).

In 2007, the LNMRI designated the Northeastern Regional Centre for Nuclear Sciences (CRCN-NE) to establish a comparison program in the Brazilian northeast region. The participation by public and private NMSs in these programs is voluntary, because there are no requirements for this from the Brazilian Regulatory Authorities.

The aim of this work is to present the results of this new comparison program in the Brazilian northeast region using sources of ^{99m}Tc, ^{131}I, ^{67}Ga, ^{201}Tl and ^{57}Co. In addition, this work presents the results of the quality control tests (zero adjust, background, high voltage, accuracy, precision, reproducibility, linearity and geometry) performed with the Standard Radionuclide Calibrator (SRC).

2. Methodology

2.1. Quality control program for the standard radionuclide calibrator

A radionuclide calibrator, Capintec, model CRC-15R, was established as the SRC. A removable support was designed as a sample holder to ensure good positioning reproducibility and to vary the distance between the source and the bottom of the chamber. The main characteristics of the radionuclide calibrator provided by the manufacturer are reported in Table 2.

This equipment was submitted to quality control tests (accuracy, precision, check source response, linearity and geometry) and the results have been analyzed following the Brazilian Norm (CNEN, 1996), since there are no requirements from Brazilian Regulatory Authorities for SSRLs. The standard CNEN-NN-3.05 provides quality control procedures for the measurement of activity only for the NMSs. The tests are described hereafter.

Accuracy is a quality control measure performed to ensure that the activity values determined by the radionuclide calibrator are traceable to national or international standards of radioactivity within the indicated uncertainties (IAEA, 2006). Precision test is to confirm that the random uncertainty of a single measurement is primarily determined by the random nature of radioactive decay (IAEA, 2006).

The accuracy and precision of the SRC were determined using standard sources. For each measurement the source was placed in the radionuclide calibrator holder and five consecutive measurements were carried out. Thereafter, the mean and standard deviation of the mean were determined. To assess accuracy, the average activity readings for the sources were compared with decay corrected certified activity (CNEN, 1996). The precision was expressed as a percentage value (the standard deviation of the measurements divided by the mean and multiplied by 100) (NPL, 2006; CNEN, 1996). In this work, these tests were performed daily.

The check source response was performed daily to assess the performance of the overall system (chamber+electrometer) and to indicate malfunction over a long period of time by measuring the activity of a long-lived standard source. This source should be free of radioactive impurities (NPL, 2006).

The linearity test shows the radionuclide calibrator's ability to measure from very low up to high activity values with a required degree of accuracy. In this work, the decaying source method was employed. A vial containing the maximum activity (4.86 GBq) of a short half-life radionuclide was measured at intervals as the source decays for a relatively long period of time (ten half-lives). For each point, 10 consecutive measurements of activity were made and the time elapsed between measurements were recorded. Then, the measured activities were plotted as a function of time and the experimental results were compared to the predicted theoretical behavior.

The response of a radionuclide calibrator depends on measuring conditions, container types (vial or syringe), material (glass or plastic), position of the radioactive sample inside the chamber well, volume and composition of the sample. Therefore, to obtain the accurate activity measurements, it is fundamental to use the appropriate correction factors for the radionuclide in the specific geometry in which the measurement is performed (Zimmerman and Cessna, 2000; Ceccatelli et al., 2007; Tyler and Woods, 2003; Mansanet et al., 2007). According to IAEA (2006), new correction factors must be determined for every change in measurement geometry for