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Performance of dose calibrators in Brazilian hospitals for activity measurements

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Abstract

In order to obtain information on the accuracy of activity measurements in Brazilian hospitals, several intercomparison exercises have been organized since 1998. The first exercise consisted of two intercomparison runs of ^{131}I and ^{99m}Tc and had the participation of 21 hospitals localized in Rio de Janeiro city and surroundings. The second, with ^{131}I (47 hospitals) and ^{123}I (12 hospitals), had the participation of hospitals localized in the whole country. The results were analyzed under the statistical point of view and conformity to the norms of Regulatory Authority. These results have shown that such exercises are necessary to improve the quality of the measurements and to identify those instruments that are producing incorrect values.

1. Introduction

Since 1998, the National Laboratory for Ionizing Radiation Metrology (LNMRI)/Brazil has been conducting intercomparison programs with Brazilian hospitals in order to check the performance of their "dose" or radionuclide calibrators (Iwahara et al., 2001). The program started with ^{131}I with the participation of 21 hospitals localized at Rio de Janeiro city and surroundings. In the same year, the second intercomparison was organized with ^{99m}Tc and 19 hospitals localized in the same region. These intercomparison runs were considered regional because they comprised only hospitals located in one state in Brazil. The second intercomparison run of these radionuclides with the same hospitals was carried out in 1999 and the results have shown an improvement in the performance of the dose calibrators when compared with the first runs. These results have encouraged LNMRI to continue with the intercomparisons, inviting hospitals from the entire country to participate. Thus, in 2000, a national intercomparison of ^{131}I with 44 participants and of ^{123}I with 12 participants was organized with the participation of hospitals localized from the entire country.

The radionuclide ^{123}I has been produced in Brazil since 1998 and is gradually replacing ^{131}I as the radiopharmaceutical for thyroid diagnosis. At present time, there are about 18 hospitals in Brazil using this radionuclide. This fact awakened concern by the medical community for the accuracy of activity measurements made with dose calibrators for this radionuclide. There are no requirements from the Brazilian Regulatory Authorities for hospitals to participate in the intercomparison. Therefore, participation was voluntary and included public and private hospitals and clinics.

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2. Methodology

In the regional intercomparison, each participant supplied the sample which was measured in its dose calibrator and sent, along with the results, to LNMRI. The participants were asked to make three measurements, removing the sample after each measurement in order to identify the effect of the slight radial displacement inside the well of the dose calibrator. At the LNMRI, the samples were measured in a CENTRONIC IG12 ionization chamber previously calibrated by primary standard solutions that had been in turn standardized by absolute measurement systems such as $4\pi\beta-\gamma$ coincidence or liquid scintillation systems. In the national intercomparison, the samples of ^{131}I and ^{123}I were distributed to the participants by the Nuclear Energy Research Institute (IPEN) and the Nuclear Engineering Institute (IEN), respectively. These two institutes are the Brazilian suppliers of radionuclides used in nuclear medicine.

3. Intercomparison

The samples of ^{99m}Tc and ^{131}I were contained in 20 ml serum vials with 5 ml of solution. The samples of ^{123}I were contained in 10 ml glass vials with 3 ml of solution. The ^{131}I and ^{123}I solutions were absolutely standardized by $4\pi\beta-\gamma$ coincidence counting and the ^{99m}Tc solution was standardized by liquid scintillation using the CIEMAT-NIST efficiency-tracing method. The vials are the geometries routinely used for activity measurements in the hospitals and in which the ionization chamber IG12 had been calibrated. The samples were also measured in the Capintec CRC-15R dose calibrator set up at LNMRI in order to determine the correction factor for those containers. All the measurements were corrected for decay to a reference date for the comparison by adopting the following half-lives: ^{131}I (8.021 ± 0.001 d) (Lagoutine, 1984), ^{99m}Tc (6.007 ± 0.012 h) (Coursol, 1982) and ^{123}I (13.21 ± 0.03 h) (Lagoutine, 1984). Each participant was given a code number in order to preserve the anonymity. The presence of radionuclidic impurities was analyzed by the germanium detector after the decay time interval of 10 half-lives. Slight ^{99}Mo breakthrough was observed in the ^{99m}Tc samples but all of them were $<0.015\%$ at the time of administration. In the case of ^{131}I and ^{123}I no detectable impurities were observed.

4. Analysis of the performance

Brazilian Regulatory Authorities require limits of $\pm10\%$ accuracy on activity measurements for radionuclides used in nuclear medicine practices. In this work we have used two criteria for performance analysis: the first is the simple relative deviation of the participant result from the reference value determined by LNMRI; second, the statistical criterion called normalized standard deviation, D, calculated as

$$D = \frac{X - U}{S_U/\sqrt{3}},$$

where X is the participant result, U the LNMRI result, adopted as the reference value, and the S_U standard deviation of the reference value.

The parameter D is used to classify the performance in good, acceptable and non-acceptable (Table 1), according to specified limits (Jarvis and Siu, 1981; Natrella, 1963).

Table 1
Normalized standard deviation

D	Performance
$-2\leqslant D\leqslant+2$	Good (within all limits)
$-3<D<-2$ or $+2<D<+3$	Acceptable (within the warning limits)
$-3\geqslant D\geqslant+3$	Non-acceptable (out of control)

In analyzing the performance of the participants, in these intercomparisons we have adopted $S_U = 0.05U$ and not the uncertainty of the measurements in the ionization chamber IG12 which are $<2\%$ (coverage factor $k = 2$) for the three radionuclides. This is a conservative approach because the accuracy goal is $\pm10\%$.

5. Results and discussion

Table 2 shows the number of dose calibrators, by brand, involved in all the intercomparisons that were carried out. Most participants used Capintec models, followed by Victoreen, the latter being based on a Geiger–Müller detector. The performance by brand in terms of the $\pm10\%$ accuracy is summarized in Table 3. The percentile distribution of the performance by brand is shown in Table 4. Considering the three models with the most participations (Capintec, Victoreen and Biodex), it can be seen that Victoreen had poorest performance demonstrating that equipment based on Geiger–Müller detector for activity measurements within $\pm10\%$ accuracy or less is not attained.

The importance of the intercomparison runs improvement of radionuclide calibrators measurement performance is shown in Figs. 1 and 2. Fig. 1 displays the comparative performance between first and second runs for the regional intercomparison of ^{131}I. In the first run, 62.5% of the results are within the $\pm10\%$ limits required by the Regulatory Authorities. In the second

Table 2
Number of radionuclide calibrators involved in the intercomparisons

Manufacturer	First and second regional intercomp. ^{131}I	First and second ofregional intercomp. ^{99m}Tc	National intercomp. ofof ^{131}I	National intercomp. of ^{123}I	Total
Victoreen	13	13	12	2	40
Capintec	8	7	32	8	55
Biodex M. S.	4	3	2	2	11
Actividigit	1	0	0	0	1
Alfa nuclear	0	0	2	0	2
Ingetron	0	0	7	0	7
Nuclear Chicago	0	0	1	0	1
Philips	0	0	1	0	1
Veccsa	0	0	2	0	2

Table 3
Summary of the performance of the results of the radionuclide calibrators

Manufacturer	Ratio R of the activities SMN/LNMRI								
	^{131}I			^{99m}Tc			^{123}I		
	$R<0.90$	$0.90\leqslant R\leqslant 1.10$	$R>1.10$	$R<0.90$	$0.90\leqslant R\leqslant 1.10$	$R>1.10$	$R<0.90$	$0.90\leqslant R\leqslant 1.10$	$R>1.10$
Victoreen	3	15	18	2	18	3	0	0	2
Capintec	3	31	2	2	12	1	2	12	0
Biodex M.S.	1	8	0	1	5	0	1	0	1
CGR M.N.	0	1	0	0	0	0	0	0	0
Alfa nuclear	0	0	2	0	0	0	0	0	0
Ingetron	2	0	5	0	0	0	0	0	0
Nuclear Chicago	0	1	0	0	0	0	0	0	0
Philips	1	0	0	0	0	0	0	0	0
Veccsa	0	2	0	0	0	0	0	0	0

Table 4
Distribution of the performance by radionuclide calibrator

Radionuclide calibrator (number of results)	$0.90\leqslant R\leqslant 1.10$	$R<0.90$ or $R>1.10$
Victoreen (61)	54.1%	45.9%
Capintec (65)	84.6%	15.4%
Biodex M.S. (17)	76.5%	23.5%
CGR médecine nucléaire (1)	100%	0
Alfa nuclear (2)	0	100%
Ingetron (7)	0	100%
Nuclear Chicago (1)	100%	0
Philips (1)	0	100%
Veccsa (2)	100%	0

run the results within $\pm 10\%$ limits increased to 72.7%, showing an improvement in the measurement performance. Under the point of view of normalized standard deviation D, in the first run 54.2% of the results are in the range good + acceptable and 45.8% are not acceptable. For the second run, these values are, respectively, 68.2% and 31.8% showing again an improvement on the performance.

Fig. 2 shows the comparative performance between first and second run for the regional intercomparison of ^{99m}Tc. Taking into account the $\pm 10\%$ limits, 78.3% of the results are within for the first run and 86.4% are within for the second. However, in terms of D, 72.7% of the results are in the range good + acceptable for both the first and second runs. By this criterion, the performance has demonstrated some deterioration because part of the results considered good have migrated to the acceptable range (52.1% in the first run and 36.3% in the second). The reason for this deterioration has not yet been found.

In the national comparison of ^{131}I, the performance was very poor, with 62.7% of the results within the limits of $\pm 10\%$ (see Fig. 3). In terms of D, 54.2% are in the range good + acceptable. The reason for this poor performance could be attributed to the many types of equipment based on Geiger–Müller detector used in this intercomparison and the fact that measurements were

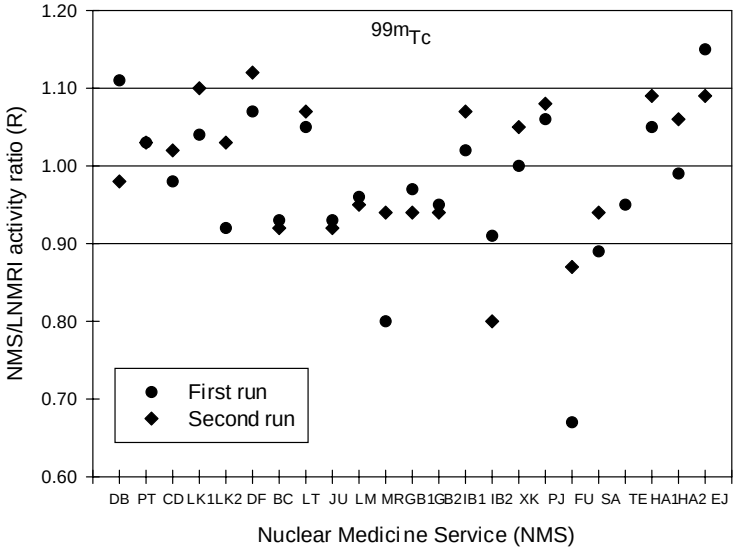


Fig. 1. Comparative performance between first and second runs of ^{131}I regional intercomparison.

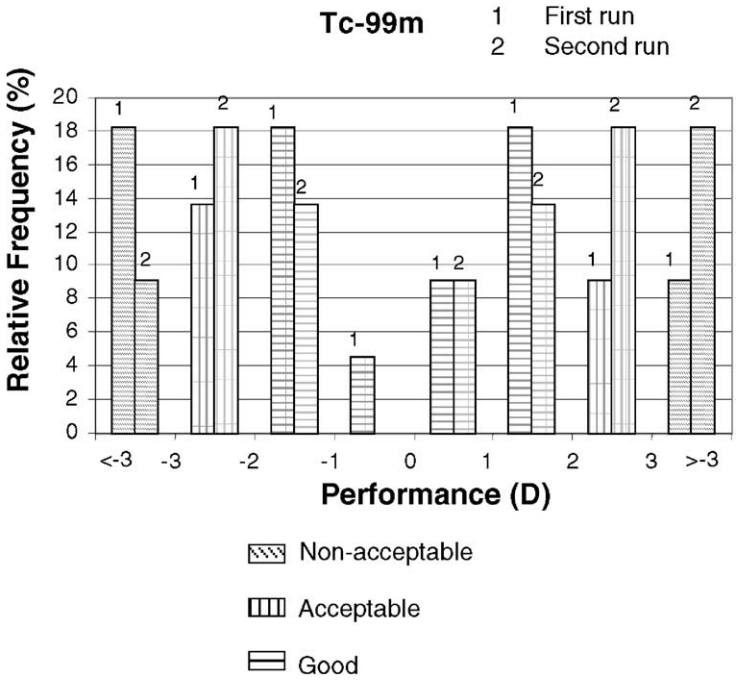
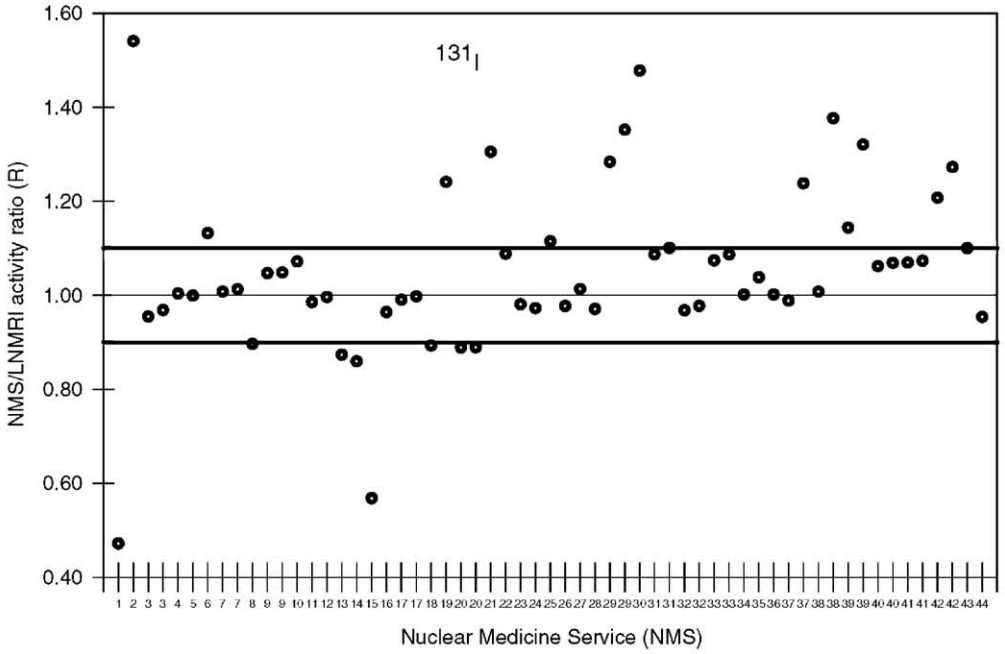


Fig. 2. Comparative performance between first and second runs of ^{99m}Tc regional intercomparison.

made by the hospitals themselves without the assistance of LNMRI. In the regional intercomparison, after the first run, many suggestions were given to the participants in order to avoid bad procedures in the measurements.

The performance of dose calibrators for the ^{123}I national intercomparison is given in Fig. 4. In terms of regulatory requirements, 66.7% are within the limits of $\pm 10\%$. In terms of normalized standard deviation D, coincidentally, 66.7% of the results are in the range



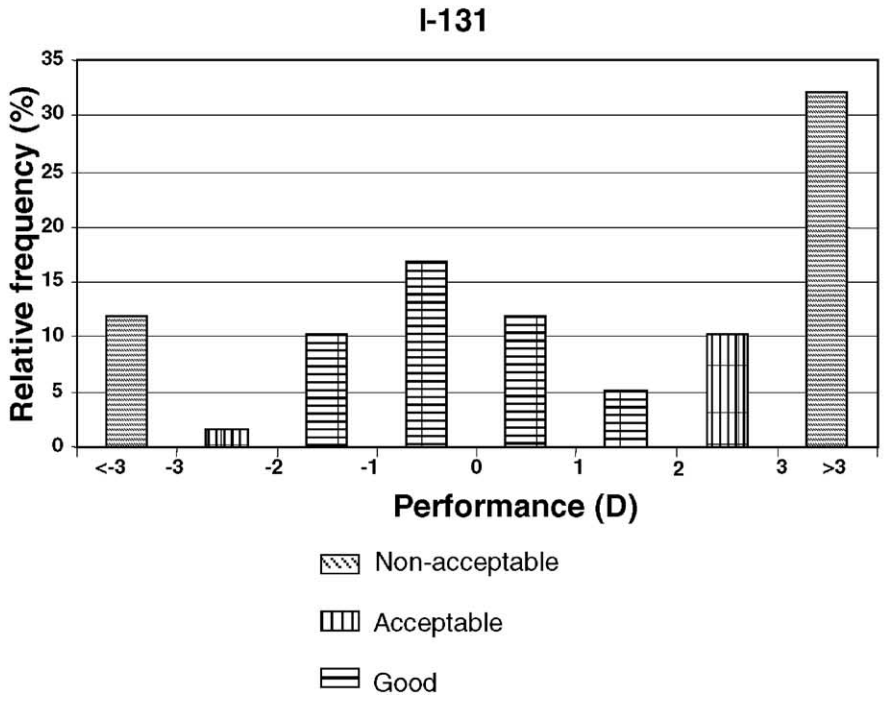


Fig. 3. Performance of the ^{131}I national intercomparison.

considered good + acceptable. In this intercomparison, only two dose calibrator are Geiger–Müller detector based, therefore this fact does not explain the poor performance.

6. Conclusions

The second runs for ^{131}I and ^{99m}Tc have shown that intercomparison are necessary in order to identify and

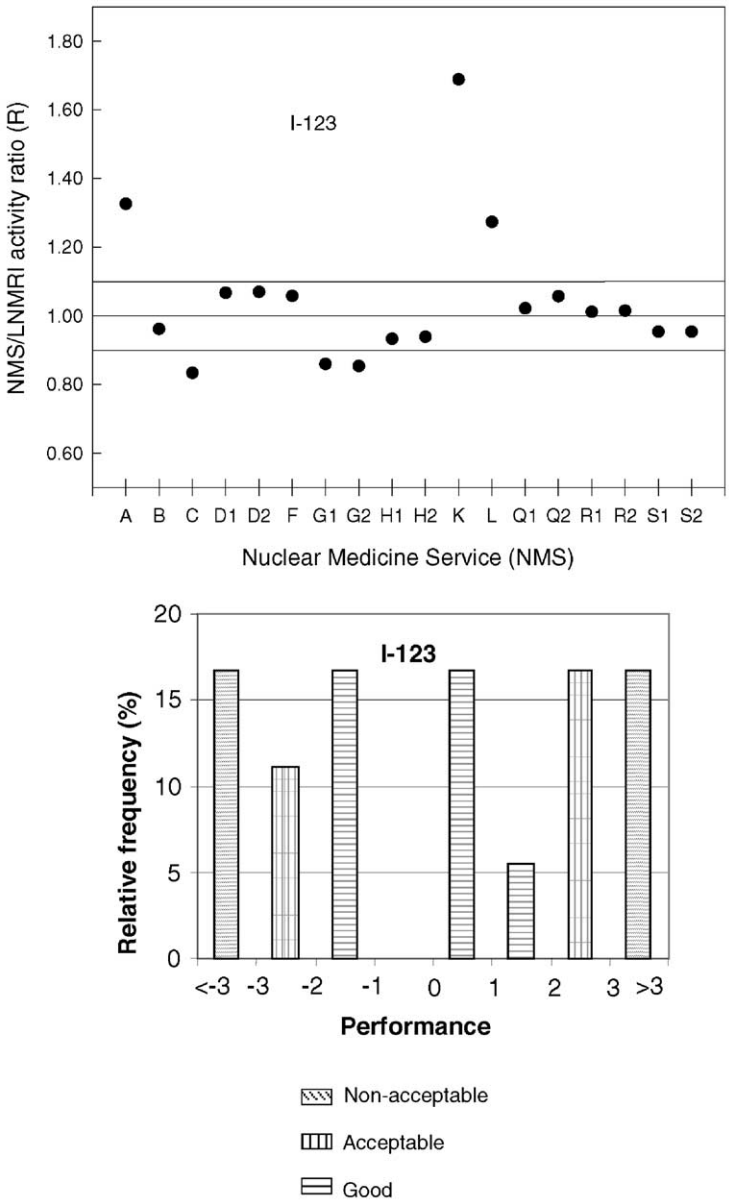


Fig. 4. Performance of the ^{123}I national intercomparison.

improve the quality of the activity measurements of dose calibrators. This can be done by exchanging information between users and radionuclide metrologists.

Dose calibrators based on Geiger–Müller detector exhibited poor performance for the three radionuclides. The reproducibility of the three measurements for ^{131}I and ^{123}I, whose low activities involved (3.7–7.4 MBq) were much poorer than that for the ^{99m}Tc (30–50 MBq), indicating that this kind of equipment is unsuitable for low activity measurements (<7.4 MBq).

Participants are asked to evaluate the uncertainty of their measurements, but most of them have declared themselves unable to do. Some of them simply communicate the uncertainty declared in the manufacturer owner's manual.

This work was carried out under the best of the participants measurements capability. A lot of work shall be done (recommendations, guides, seminars and courses) in order to improve the performance of the measurements of their radionuclide calibrators.

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