CORRECTION FACTORS OF COMERCIAL RADIONUCLIDE CALIBRATORS FOR SYRINGE GEOMETRY IN THE ACTIVITY MEASUREMENTS OF $^{99}Tc^{m}$ AND ^{123}I

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Abstract: Radionuclide calibrators are used in nuclear medicine centers (NMC) for measuring the activity of radiopharmaceuticals administered to a patient. These devices are commercially available and have been calibrated for various radionuclides using a certain type of containers characteristic of each manufacturer. However, vials of different geometries and composition are used in NMC for activity measurement in which the calibration factors may be significantly different from those used by the manufacturers to calibrate the devices. The magnitude of these differences depends on the energies of photons emitted. This work will examine the volumetric dependence on activity measurement of $^{99}Tc^{m}$ and ^{123}I using two plastic syringes (3 and 5mL) and various types of radionuclide calibrators. The results obtained have shown that large errors can be produced if the differences in the volume of solutions contained in the syringe are not considered.

Key words: radionuclide calibrator, nuclear medicine, syringe measurements, $^{99}Tc^{m}$, ^{123}I.

1. INTRODUCTION

In nuclear medicine the activity of a radiopharmaceutical shall be accurately measured to achieve the purposes of diagnosis or treatment and at the same time minimizing the dose to patient. Regulatory bodies have set the limits on the accuracy of the activity measurements. In Brazil, National Commission on Nuclear Energy (CNEN) [1] has established ±10% while international bodies like International Atomic Energy Agency (IAEA) [2] established ±5% for therapy. To determine the value of activities in the calibrator, the NMC use different types of containers. The most used are glass vials and plastic syringes with different volumes of radiopharmaceuticals. The differences in volume, geometry and composition create a need for a correction in the original calibration factors of radionuclide calibrators. This issue has been studied by several authors and published in the literature [3-5]. Before being administered to the patient, the radiopharmaceutical contained in a glass vial has its activity determined by the radionuclide calibrator. Subsequently an aliquot of this radiopharmaceutical is transferred to a plastic syringe and its activity determined again using the same calibration factor as for glass vial. This latter value is considered the activity administered. As can be seen, the radioactive liquid is handled in distinct containers with different geometries, volumes and compositions. If these discrepancies are not taken into consideration and their correction factors are not previously determined, the patient may receive an incorrect activity.

2. PURPOSE

This work aims to determine the correction factors for the volume dependence of radiopharmaceuticals contained in plastic syringe of 3 and 5 mL. Two radionuclides widely used in nuclear medicine ($^{99}Tc^{m}$ and ^{123}I) were chosen with radionuclide calibrators using ionization chamber (IC) and Geiger-Müller (G-M) detectors. The performance of radionuclide calibrators used routinely in NMC of Rio de Janeiro city for activity measurements in syringe geometry was analyzed for $^{99}Tc^{m}$. The performance criterion used was the Brazilian norm CNEN NN-3.05 that requires limits of ±10% in accuracy for activity measurements in the radionuclide calibrator.

3. METHODS

In this work the volume correction factors have been determined from practical measurements of the variation of in the response (activity) of the radionuclide calibrator with the volume of solution in the container. Two plastic syringes of 3 and 5 mL BD Plastipak type, manufactured by Becton Dickinson Ind. Cirúr. Ltda. Brazil were selected for this work. The choice of these models and types occurred by being widely used in the NMC of Rio de Janeiro city. The sources of $^{99}Tc^{m}$ were provided by IPEN/São Paulo and ^{123}I by IEN/Rio de Janeiro. Measurements were carried out in three radionuclide calibrators installed at Radionuclide Metrology Laboratory (SEMRA) of National Metrology Laboratory for Ionizing Radiation (LNMRI): two with IC as detector and the third with G-M detector. The 5 mL syringe was firstly filled with 1 mL of $^{99}Tc^{m}$ solution and the activity in three calibrators read. Then successive volumes of 1 mL of distilled water were added and re-measuring the syringe after each addition until completes 5 mL. The same procedure was repeated with the 3 mL syringe, but with initial volume of 0.5 mL and adding successively 0.5 mL of distilled water until complete 3 mL. The procedure was the same for ^{123}I. For performance test of radionuclide calibrators, solutions of $^{99}Tc^{m}$ contained in syringes of 3 and 5 mL were used to compare the activities measured by NMC with the activities measured by standard reference systems of LNMRI. The criterion of comparison adopted for performance analysis is the limit of accuracy of ±10% established by CNEN, i.e., the ratio R of activity A, measured by a NMC to the activity A_0, measured by LNMRI, adopted as reference, falls within $0.90<R<1.10$.

4. RESULTS

Fig.1 and 2 show the results obtained for the $^{99}Tc^{m}$ measured with 3 and 5 mL syringe volume, respectively, in three different radionuclide calibrators: Capintec CRC-15R, Vexcal and Victoreen Cal-Rad 34-061. The first two use ionization chamber while the latter the G-M as detector. Fig. 3 and 4 show the results for ^{123}I. The activity A_0 at the normalizing volume V_0 of $^{99}Tc^{m}$ or ^{123}I solution was determined by plotting the activity A against the individual volume V and using the activity at V_0=1 mL. These data were used to plot A/A_0 against V in Fig. 1 to Fig. 4. A second-degree polynomial was used as the best approach to give the volume correction factor represented by the following equation:

$$\frac{A}{A_0} = a\,V^2 + b\,V + c$$

where A_0 is the activity expected at the normalizing volume V_0 (1 mL) and A is the measured activity at an individual volume V. Table 1 and 2 display the volume correction factors coefficients of $^{99}Tc^{m}$ for 3 and 5 mL syringes and Table 3 and 4 for 3 and 5 mL syringes for ^{123}I.

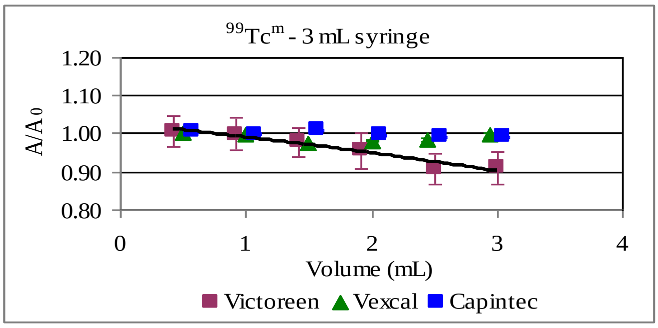

Fig. 1. Results of 3 mL syringe for $^{99}Tc^{m}$

Table 1. Volume correction factors coefficients of a second-degree polynomial for $^{99}Tc^{m}$ in 3 mL syringe.

Radionuclide calibrator	Volume correction factor coefficients		
	a	b	c
Victoreen 34-061	-0.003094	-0.032417	1.026263
Capintec CRC-15R	-0.002371	0.002504	1.004153
Vexcal	0.013844	-0.052121	1.028334

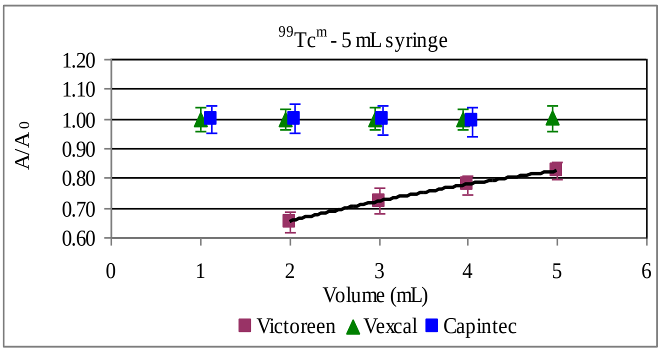

Fig. 2. Results of 5 mL syringe for $^{99}Tc^{m}$

Table 2. Volume correction factors coefficients of a second-degree polynomial for $^{99}Tc^{m}$ in 5 mL syringe.

Radionuclide calibrator	Volume correction factor coefficients		
	a	b	c
Victoreen 34-061	-0.0053214	-0.093971	0.486746
Capintec CRC-15R	-0.000691	0.003397	1.002647
Vexcal	0.001011	-0.002319	0.998683

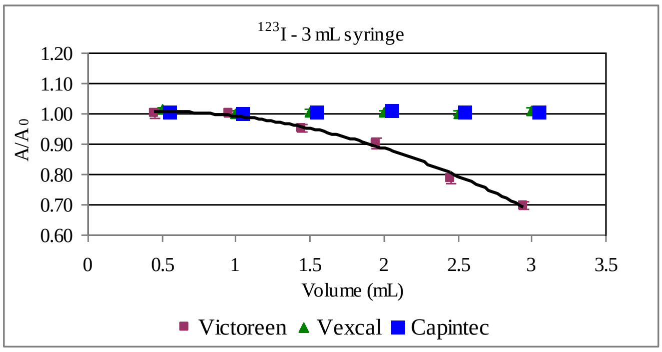

Fig. 3. Results of 3 mL syringe for ^{123}I

Table 3. Volume correction factors coefficients of a second-degree polynomial for ^{123}I in 3 mL syringe.

Radionuclide calibrator	Volume correction factor coefficients		
	a	b	c
Victoreen 34-061	-0.0050397	0.044860	0.996044
Capintec CRC-15R	-0.002598	0.010525	0.995670
Vexcal	0.04285	-0.017067	1.018526

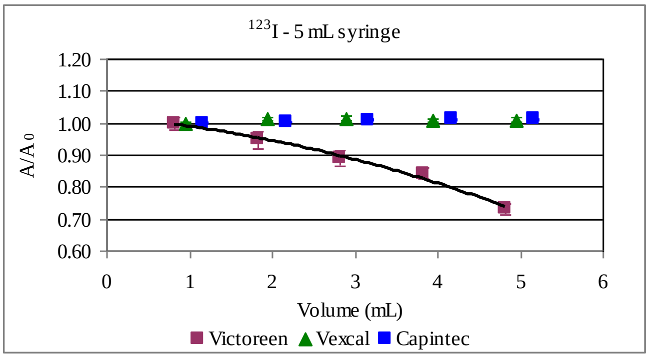

Fig. 4. Results of 5 mL syringe for ^{123}I

Table 4. Volume correction factors coefficients of a second-degree polynomial for ^{123}I in 5 mL syringe.

Radionuclide calibrator	Volume correction factor coefficients		
	a	b	c
Victoreen 34-061	-0.007684	-0.020918	1.017485
Capintec CRC-15R	-0.000689	0.007541	0.991423
Vexcal	-0.002474	0.016061	0.988927

Plastic syringes of 3 and 5 mL containing 1 mL of ^{99}Tc^{m} with known activity were used for performance test of several types of radionuclide calibrators. Four NMC of Rio de Janeiro city with 5 radionuclide calibrators and 3 set up at LNMRI took part in this test and results were analyzed from the standpoint of the criterion of accuracy of CNEN established in the norm NN-3.05. Fig. 5 displays the results of this performance test of 3 and 5 ml syringes for ^{99}Tc^{m} in 8 radionuclide calibrators.

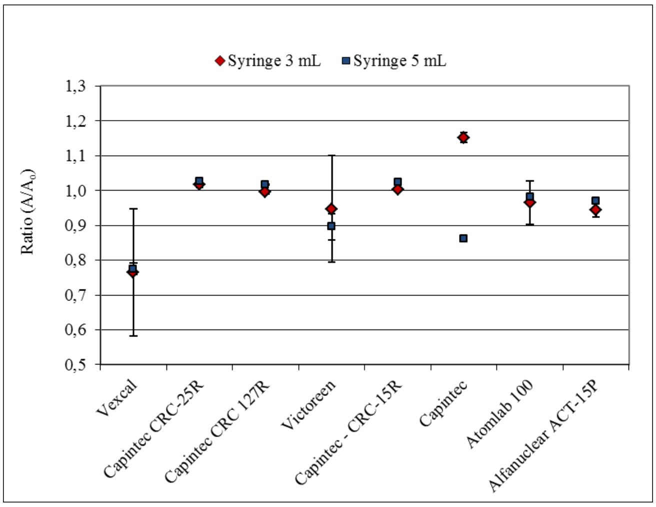

Fig. 5 Comparison or activity measurements of ^{99}Tc^{m} contained in plastic syringes

5. DISCUSSION

For 3 mL syringe of ^{99}Tc^{m} the variation in volume from 1 to 3 mL did not cause a significant change of activity measured in Vexcal and Capintec calibrators. However, the model Victoreen showed a wider variation reaching a value about 10% smaller when increasing the volume from 1 to 3 mL. The same behavior was found for the 5 mL syringe for the two calibrators with IC but the data measured for Victoreen didn't show results consistent with those expected. New measurements should be done to check this inconsistency. The values of the correction factors coefficients also show that the calibrator Victoreen presents the most variation.

For ^{123}I the behavior is similar to ^{99}Tc^{m} for three calibrator models. Again the largest variation was found with the Victoreen model where the measured activities at 3 and 5 mL were 70% lower for both the syringe when compared to the activity of the standard volume of 1 mL. This greater variation compared with ^{99}Tc^{m} can be explained by the strong absorption in the sample itself of numerous characteristic X-rays of low energy emitted by ^{123}I which contribute to produce the activity read by the calibrator. The correction factors evaluated are only valid for the calibrators and types of syringes studied in this work. The owners of radionuclide calibrators should determine their own correction factors for each type of container in different volumes.

In checking the performance of different calibrators for ^{99}Tc^{m} there is a similar behavior for syringes of 3 and 5 mL. Among the eight calibrators tested only two had their performance beyond the limits of accuracy required by the Brazilian standards. The exception is the number 6 that had a contradictory behavior requiring a new measurement for further verification.

5. CONCLUSION

The results confirm that the response of calibrators depend on the volume contained in the syringe and it is more critical for that with G-M detector analyzed in this work, reaching a score of up to 70% lower than the response of the standard volume. To have more robust findings with syringe measurements at NMC the number of participants in the comparison must be increased. As the NMC use different types of containers with varying volumes of radiopharmaceuticals they must determine the corrections factors required to administer the correct activities in order to minimize unnecessary doses to patients. Further work is needed involving other radionuclides such as ^{67}Ga, ^{201}Tl, ^{111}In and others. This work is not recommending or advertising this or that radionuclide calibrator model, but only describing the performance results of the calibrators studied.

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