PERFORMANCE OF A DOSE CALIBRATOR FOR RADIOACTIVITY MEASUREMENTS OF ^{99M}TC-GENERATOR MANUFACTURED AT MALAYSIAN NUCLEAR AGENCY

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ABSTRACT

We sought to test the performance of a dose calibrator for radioactivity measurements of ^{99m}Tc generator manufactured at the Malaysian Nuclear Agency. Parameters tested are accuracy, constancy and linearity. Result of accuracy test using ^{137}Cs, ^{60}Co and ^{57}Co reference sources were (-2.80%) and (2.62 to 2.72%) respectively. While result of constancy test using ^{137}Cs and ^{99m}Tc were (0.002 to 0.023%) and (-0.008 to -0.01%) respectively. The result of linearity test using ^{99m}Tc shows the diference of less than 10% between the measured and calculated radioactivity. The plot shows an excellent linearity between 19 mCi to 305 mCi. It indicates that the dose calibrator for radioactivity measurements of ^{99m}Tc generator manufactured at the Malaysian Nuclear Agency was giving the actual prescribed radioactivity. This may ensure traceability of measurements of the radioactivity of ^{99m}Tc used in nuclear medicine practice.

ABSTRAK

Prestasi alat tentukuran dos untuk pengukuran radioaktiviti penjana ^{99m}Tc yang dihasilkan di Agensi Nuklear Malaysia telah diuji. Parameter yang diuji adalah ketepatan, ketetapan/kemalaran dan kelinearan. Keputusan ujian ketepatan menggunakan ^{137}Cs, ^{60}Co dan punca rujukan ^{57}Co adalah (-2.80%) dan (2.62 hingga 2.72%). Keputusan ujian ketetapan/kemalaran menggunakan ^{137}Cs dan ^{99m}Tc adalah (0.002 hingga 0.023%) dan (-0.008 hingga 0.01%). Keputusan ujian kelinearan menggunakan ^{99m}Tc menunjukkan perbezaan yang tidak melebihi 10% di antara radioaktiviti yang diukur dan yang dikira. Plot menunjukkan kelinearan yang sangat baik antara 19 mCi hingga 305 mCi. Ini menunjukkan bahawa alat tentukuran dos untuk ukuran radioaktiviti penjana ^{99m}Tc yang dihasilkan di Agensi Nuklear Malaysia memberikan radioaktiviti sebenar. Maklumat yang diperolehi telah memberi kepastian kebolehkesanan pengukuran radioaktiviti ^{99m}Tc digunakan dalam amalan perubatan nuklear.

Keywords : ^{99m}Tc Generator, dose calibrator and radioactivity measurement

INTRODUCTION

In nuclear medicine, the determination of radioactivity injected to the patients plays an important role for the success of the therapy or the diagnosis procedure (Fragoso *et al.,* 2010). ^{99m}Tc is the most widely used radionuclide in nuclear medicine diagnostic procedures partly due to the uncomplicated and flexible way of obtaining it from ^{99}Mo/^{99m}Tc generator. Malaysian Nuclear Agency is a sole manufacturer of ^{99m}Tc generator in the country. The measurement of radioactivity using the dose calibrator is the only assurance that the ^{99m}Tc generator manufactured is giving the actual prescribed radioactivity. Thus, elaborate performance evaluation of the dose calibrator is required (AAPM, 2012).

The dose calibrator is a pressurized gas-filled ionization chamber for measuring radioactivities in radiopharmaceutical vials, syringes and in other small containers (Zanzonico, 2008). The response of dose calibrator depends on many factors including background, ambient temperature and pressure (Samson,1999). Code of Federal Regulations, CFR 10, Part 35.60 (CFR 10, 2010) specifies that the dose calibrator tests should include accuracy, consistancy, linearity and geometry. It also recommends that a licensee shall calibrate the dose calibrator in accordance with the nationally recognized standards or the manufacturer's instructions. It further specifies that accuracy should be tested at installation and annually thereafter; consistancy should be tested at installation and daily thereafter; linearity should be tested at installation and quarterly thereafter; and geometry should be tested at installation and after repair or any movement.

Accuracy test is designed to show that the calibrator is giving correct readings throughout the entire energy scale, one is likely to encounter. Constancy test is designed to show that reproducible readings are obtained in measuring a constant source over a long period of time. Linearity test is designed to measure dose calibrator's ability to measure a known radioactive sources varying from the µCi range through the mCi range (Zanzonico, 2008, CFR 10, 2010 and Zeinali *et al,*. 2008).

The objective of this study was to test the performance of a dose calibrator use for radioactivity measurements of ^{99m}Tc generator manufactured at the Malaysian Nuclear Agency. This will further ensure traceability of radioactivity measurements of ^{99m}Tc used in nuclear medicine practice throughout the country.

MATERIALS AND METHOD

A dose calibrator model CRC-127R (Capintec, Inc., Ramsey, NJ) was used in this study. It underwent annual calibration test by the Secondary Standard Dosimetry Laboratory (SSDL). The experiment was carried out at room temperature, in the product packaging area. Since in many instances, performance tests of nuclear medicine instrumentation (including dose calibrator) are performed not with the radionuclides that are used clinically but with longer-lived surrogate radionuclides in the form of co-called reference sources (Zanzonico, 2008). We chose to use point standard sources for testing accuracy and constancy. ^{99m}Tc in a form of solution in a vial was used for testing linearity.

For the accuracy testing, low, medium, and high energy standards sources (^{57}Co, ^{137}Cs and ^{60}Co) with activities of 5.510 mCi, 9.644 µCi and 6.112 µCi were used. Their radioactivities were measured in the dose calibrator using their respective settings. The value on the label indicating the radioactivity of the standard sources, at a specific calibration time and date is mathematically decay-corrected to the testing date. Decay-correct source activities were calculated at time of measurements. All measured radioactivity were corrected from background. For each standard source, the measured radioactivity were obtained several times on each scale and its current actual radioactivity were compared with the standard values. Measured values should be within ± 10% (CFR 10, 2010 and Zeinali *et al,*. 2008] or ±5% (Capintec, 2009) of the standard value.

Constancy test was performed by placing ^{137}Cs in the dose calibrator. Radioactivity was then measured on the ^{137}Cs and ^{99m}Tc settings respectively. Five readings were taken for each measurement everyday for five consecutive days. The average was then calculated. The values were compared with decay corrected activities to determine if the instrument is performing consistently on a day-to-day basis. Measured radioactivity should be within ± 10% of the standard value (CFR 10, 2010).

Linearity test was performed by measuring activities of ^{99m}Tc source (305 mCi) using a decay method (Capintec, 2009 and Santry, 1989). Radioactivity was measured at an interval of 0, 6, 24, 30, 48, 54, 72 and 78 hours respectively. Average of five measurements was calculated for each measured radioactivity. The measured radioactivity was plotted as a function of time and the experiment results was compared with the theoretical behavior.

RESULTS AND DISCUSSION

Table 1 displays the data collected during the accuracy test. Measured radioactivity and its current actual radioactivity agreed to within 10 % (CFR 10, 2010 and Zeinali *et al.,* 2008) and 5% (Capintec, 2009). Result of accuracy test using ^{137}Cs, ^{60}Co and ^{57}Co reference sources were (-2.80%) and (2.62 to 2.72%) respectively. The dose calibrator accuracy test showed that the unit functions well within the dose calibrator's specifications.

Table 2 displays the data collected during a daily constancy test over a one-week time period. It shows that results of constancy test using ^{137}Cs and ^{99m}Tc were (0.002 to 0.023%) and (-0.008 to -0.01%) respectively. The dose calibrator has passed the test. No measurements differ from the corresponding calculated radioactivity by more than ±10%. Measured values were found to be less than ±10% (CFR 10, 2010) of the standard value. The dose calibrator constancy test show that the unit functions well within the dose calibrator's specifications.

Table 3 shows that linearity of dose calibrator tested was also very good, not exceeding the limit of ± 10 % for all radioactivity settings. Fig 1 shows results of both theoretical and measured activities. It demonstrates that the dose calibrator tested presents a linear response from 305 mCi down to 19 mCi. The results is in accordance to the limits set by CFR (CFR 10, 2010).

Table 1: Results of the accuracy test

Standard source	Average Calculated Radioactivity (A) (µCi)	Average Measured Radioactivity (C) (µCi)	Accuracy ((A-C)/C x 100%)
^{57}Co	3436.000	3534.000	-2.80
	3436.000		-2.80
	3438.000		-2.80
	3436.000		-2.80
	3436.000		-2.80
^{137}Cs	9.932	9.644	2.99
	9.935		3.02
	9.933		3.00
	9.933		3.00
	9.933		3.00
^{60}Co	6.272	6.112	2.62
	6.272		2.62
	6.278		2.72
	6.274		2.65
	6.272		2.62

Table 2: Results of constancy test

Day	Setting					
	^{137}Cs			^{99m} Tc		
	Average Measured Radioactivity (A µCi)	Average standard value (C µCi)	Constancy ((A-C)/C x 100%)	Average Measured Radioactivity (µCi)	Average standard value (C µCi)	Constancy ((A-C)/C x 100%)
1	9.956	9.933	0.023	9.825	9.925	-0.01
2	9.948	9.933	0.002	9.828	9.925	-0.01
3	9.949	9.933	0.002	9.825	9.925	-0.01
4	9.982	9.933	0.005	9.848	9.925	-0.008
5	9.988	9.933	0.006	9.824	9.925	-0.01

Table 3: Results of linearity test

Measuring time (hr)	Measured Radioactivity (A) (mCi)	Expected Radioactivity (C) (mCi)	Difference ((A-C)/C x 100%)
0	305.071	305.000	0.023
1	271.45	276.533	-1.838
2	241.967	245.017	-1.201
3	215.530	212.483	1.434
6	152.500	150.467	1.351
12	76.251	73.607	3.592
24	19.063	19.418	-1.828
48	1.190	1.210	-1.653
72	0.074	0.075	-1.333
78	0.037	0.038	-2.632

The results obtained from this study are similar to those results reported by SSDL (MNA, 2008). However, the calibration was done using standard sources of ^{57}Co, ^{133}Ba, ^{137}Cs and ^{60}Co for the accuracy test, ^{137}Cs for constancy test and using shield method for the linearity test.

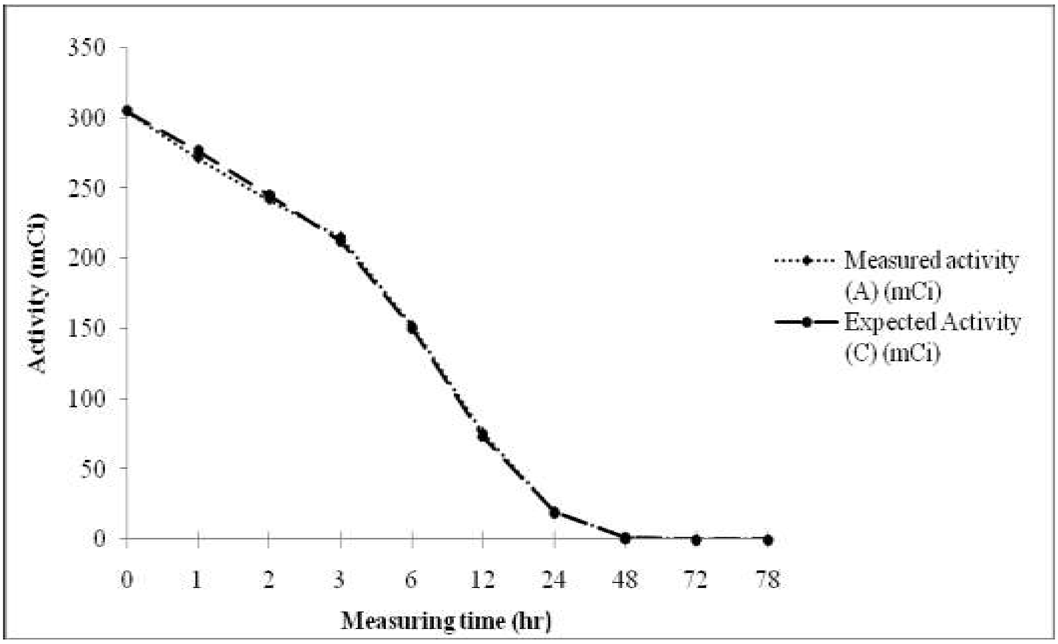

Figure 1. A plot showing results of the linearity test. Square represents the theoretical data and round represents measured data.

CONCLUSION

In conclusion, this work demonstrated that the dose calibrator tested behaved in a consistent and repeatable manner and is functioning well within the specifications. It indicates that dose calibrator for radioactivity measurements of ^{99m}Tc generator manufactured at the Malaysian Nuclear Agency is giving the actual prescribed radioactivity. This may ensure traceability of measurements of the radioaactivity of ^{99m}Tc used in nuclear madicene practice throughout the country.

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