Assessment of ^{99m}Tc Dose Calibrator Performance in Nuclear Medicine Department

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Abstract: ***Nuclear medicine uses many different radioactive isotopes for radiation diagnostics and for therapy. The amount of radioactivity has to be determined exactly before it is applied to a patient. The Dose calibrators have to measure the radioactivity of gamma and beta with different energies precisely for high quality imaging and for applying the right amount of radiation to treat disease. This study was carried out to assess the performance of dose calibrators which work in nuclear medicine departments in Khartoum state. Two departments were included in this study, Radiation and isotopes center of Khartoum (RICK) and Elnileen medical diagnostic center. Four quality control tests were carried out using two standard Radionuclides, ^{137}Cs and ^{57}Co, which were accuracy, constancy, linearity and geometry. All results that obtained from the study has been compared with the international standard (±5%) and the results showed that all dose calibrators has good performance and there is no need for any correction tables or factors or maintenance.***

Keywords: Nuclear medicine, dose calibrator, quality control.

1. Introduction

Nuclear medicine procedures use many different radioactive isotopes for radiation diagnostics and for therapy. The amount of radioactivity has to be determined exactly before it is applied to a patient. The isotope calibrators have to measure the radioactivity of gamma and beta emitting isotopes with different energies precisely for high quality imaging and for applying the right amount of radiation to treat disease. They must be able to measure low isotope activities for patient application and high activities during isotope production. The isotope calibrators should allow easy and fast operation in routine work as well as quick and effective cleaning in case of contamination. Continuous quality control of isotope calibrators is mandatory according to international standards and guidelines such as international electro technical committee, IEC 61303 "Medical electrical equipment – Radionuclide calibrators – Particular methods for describing performance". Those methods include background measurement, accuracy, reproducibility and linearity checks as well as contamination tests. All these parameters influence the quality of activity measurements and consequently the radiation load for the patients. The high quality isotope calibrators assist responsible staffs in nuclear medicine laboratories to perform precise activity measurements and to fulfill the ICRP 60 requirement to keep the radiation load as low as achievable for patients. The radionuclide activity dose calibrators are routinely used in nuclear medicine practices to quantify the radioactivity dose of the radiopharmaceuticals to be administered to the patients. According to the current standards and regulations for NM worldwide practices, including those adopted by the international atomic energy agency (IAEA), and national regulations such as those promulgated by the United States Nuclear Regulatory Commission (U.S.NRC), the radioactivity of any radiopharmaceutical that contains a photon-emitting radionuclide must be measured by a dose calibrator prior to administration to patients or for human research purposes. Obviously, the administration of the prescribed amount of activity to the patient requires proper operation of the dose calibrator, which shall be verified by implementing the required quality control tests on the instrument. Several quality control tests are necessary to ensure the proper operation of the dose calibrators, among which the tests for the linearity of the response, accuracy, precision, and physical functioning of the instrument are of more importance. The linearity of the response test confirms the ability of the instrument to measure a range of low to high activity doses with a required degree of accuracy. It is important that the linearity of the response of the dose calibrator to be ascertained over the range of its use between the maximum activity administered and 1 MBq. It has been recommended that the test to be carried out upon acceptance, repair, and then annually. This test is mostly carried out by measuring a high activity, short-lived radionuclide for a given period of time by the instrument. Typically, Tc-99m is used for this purpose. Accuracy is a quality control measure performed upon acceptance, repair, and then annually, to ensure that the activity values determined by the dose calibrator are traceable to national or international standards of radioactivity within the indicated uncertainties. Precision test is to confirm that the random uncertainty of a single measurement is primarily determined by the random nature of radioactive decay. A larger than expected value indicates the possible presence of another random source of uncertainty that had not been anticipated. The recommended values for the above QC measures are within +/- 5 to 10 %, depending on the radionuclide of interest and measurement conditions

2. Methods and Materials

2.1 Physical Inspection

Dose calibrator was inspected the instrument housing for evidence of damage. Particularly it was examined the surroundings of the ionization chamber for signs of deformation or indentation. It was inspected all controls plug-in modules push buttons and switches. It was inspected all controls, check that none were missing and examine cables, plugs and socket for evidence of damage. All accessories was inspected such as remote handing devices source holders; check that none are missing or damage. He checked any accompanying sealed radiation sources for external radioactive contamination or leakage. Both operation and service manuals checked that are available. The compatibility of the power supply requirements checked with available supply and makes any necessary adjustments. He initiated the instrument log-bookmaking an inventory of the instrument and its accessories and recording their condition on and the action taken to correct them.

a) Background Test

In early morning researcher switch-on the instrument (wait 5 min for stabilization) then Q.A button would press on dose calibrator to measure background. Then he press enter (F5) to initiate measurement. The reading recorded in mCi units.

b) Reproducibility

The check source put in the holder and then put it in the chamber. The reading recorded in mCi units. The steps repeated above for 10 measurements.

c) Clock Accuracy

It is the stabilization of time between two measurements (time required for any measurement should be same). The holder put in ionization chamber. The value was appearing stop the stop watch and recorded the time. He repeated steps above for 10 successive measurements.

d) Accuracy

The accuracy of a measurement is determined by how close it is to the true value (reference condition).

e) Precision Test

Precision is a measure of the spread of values obtained from a sequence of measurements. It is usually defined in terms of the standard deviation of a set of 10 consecutive measurements. Reading. He repeated steps above for 10 successive measurements.

f) Zero adjustment

Zero adjustment compensates for any non-ideal characteristics of the electronic measuring system of the radionuclide dose calibrator. The system must be zeroed if the measuring value is negative this status is indicated by the massage zero electrometer flashing at the top of the display. The system should be zeroed when it is put in to service, when the measurement conditions change or after considerable changes in temperature.

g) Linearity test

h) The purpose of this test is to test the linearity of the activity response of a radionuclide calibrator over the range of activities for which it is to be used. There are two methods for this test, Decaying source method and Graded sources method. Researcher inserted the source sample into the holder and introduces the source holder into the dose calibrator instrument. He selected Tc-99m radionuclide. He pressed enter button (F5) to initiate measurement. He recorded the reading (take 5) and exact time of measurement.

3. The Results

This is an experimental study deals with evaluation of quality control program of Technetium-99m (99Mo-99mTc) Generators dose calibrator. The importance of this study is to highlight the importance of the quality assurance program in nuclear medicine department. In addition to its role to increase diagnosis accuracy and reduce the dose to both patient that is unable to reach by without quality control special in Technetium-99m (99Mo-99mTc) Generators. The main objective of this study is to assess the performance of the dose calibrators that is being used in nuclear medicine departments. For nuclear medicine, each dose calibrator was being tested for accuracy, constancy, geometry and linearity, where the acceptable level of the tests was determined. T-test was been performed for all score variations in this study. P-value was calculated to show if there is any significant impact of each dose calibrator test i.e.:

P-value >0.05 no significance
P- Value <0.05 significant.

3.1 Background Test

The background measurement determines the basic ionizing radiation in the vicinity of the measuring system.

Table 1: Shows background test

First reading	0.83 mCi
Second Reading	0.92 mCi
Mean	0.875mCi
SD	0.045

3.2 Reproducibility Test

The test has been carried out to check the day reproducibility of performance of radionuclide calibrator in measurements on commonly used radionuclide in N.M department.

Table 2: Shows reproducibility test of radionuclide calibrator

No	*Reading in mCi*
1	155.3
2	155.8
3	155.7
4	155.7
5	154.6
6	154.7
7	154.4
8	155.1

9	155.4
10	155.1
Mean	155.08
SD	0.579

3.3 Clock Accuracy

It is the stabilization of time between two measurements (time required for any measurement should be same).

Table 3: Shows clock accuracy test of radionuclide calibrator

No	*Reading (seconds)*
1	1.79
2	1.50
3	1.21
4	1.28
5	1.21
6	1.17
7	1.08
8	1.13
9	1.11
10	1.04
Mean	1.26
SD	0.462

3.4 Accuracy

The accuracy of a measurement is determined by how close it is to the true value (reference condition).

Calculation

C at 3 / 8 /2013 for Cs-137 is equal:

$T_{1/2} = 30$ year

C_0 (certified activity) = 187mci at 1/4/2007

$C = C_0 e^{-\lambda t}$

$\lambda = \frac{\ln 2}{T_{1/2}}$ Year $^{-1}$

$t = (6.3)$ years

A = Mean (Form the reading)

Accuracy % = $\frac{A - C}{C} \times 100$

Accuracy % = $\frac{155.4 - 161.7}{161.72} \times 100 = 0.039\%$

Table 4: Shows accuracy test of radionuclide calibrator

No	*Reading (mci)*
1	155.0
2	155.4
3	155.7
4	155.2
5	155.5
6	155.8
7	155.2
8	155.6
9	155.4
10	155.1
Mean	155.4
SD	0.217

3.4 Precision Test

Precision is a measure of the spread of values obtained from a sequence of measurements. It is usually defined in terms of the standard deviation of a set of 10 consecutive measurements.

Table 5: Shows precision test of radionuclide calibrator

No	*Reading in mCi Unit*
1	2.768
2	2.765
3	2.769
4	2.771
5	2.773
6	2.776
7	2.780
8	2.780
9	2.781
10	2.782
Mean	2.7745
SD	0.006

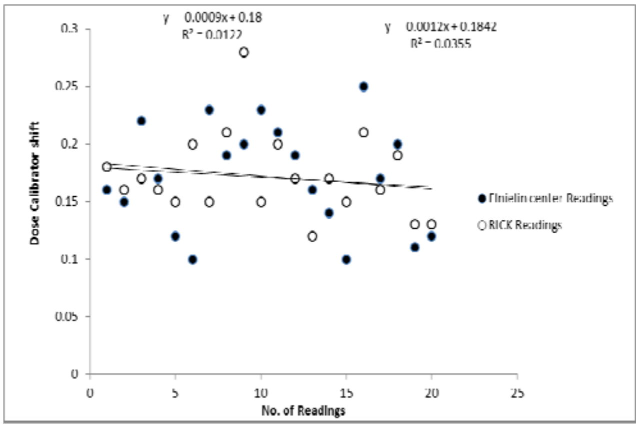

Figure 1: Shows the mean and standard deviation of Geometry test of dose calibrator measured in Elnielin Center and Radiation Isotopes Center of Khartoum (RICK)

Independent t-Test on Geometry test of dose calibrator of Elnielin Center and Radiation Isotopes Center of Khartoum (RICK) showed that t = 0.07628 with p = 0.93959 at the 0.05 level, which mean that the two means are NOT significantly different.

4. Conclusion

The results concerning quality control of Dose Calibrator in Khartoum Hospital were obtained by different methods. Departmental organization requires long-term planning. It is good to find a solution when a problem arises, but it is better to foresee the problem so that it can be avoided. Short-term policy often leads to confusion among personnel, and this reduces motivation. Diagnostic procedures in nuclear medicine should be correct the first time. Concerning the physical inspection test was good, it was clear that these features help in providing good outcomes in terms of imaging capacity of the department. It was found that imaging procedures are so organized that every particular study is usually done on a known separate day during the week, and this minimizes errors during a radiopharmaceuticals preparation. Concerning the background test, the result of test was good and in normal exposure range (0.785 +.45 mCi) as showed in table 1. The implementation of radiation protection rules was good in some aspects of the work. No in-house preset standards that were available in printed manuals and also no check listed and permanent records. The involvement of technologists directly in management may increase the implementation of the rules concerning quality control of radiopharmaceuticals. The results concerning the reproducibility test of radionuclide calibrator, the day reproducibility of performance of radionuclide calibrator was good with very error (155.08 + 0.579) as showed in table 2. Concerning the training of staff, it is better to increase it by short training courses, especially in area of quality control in nuclear medicine. Concerning clock accuracy, the stabilization of time between two measurements showed no significant different as showed in table 3. The results obtained concerning accuracy showed that the dose calibrator has accurate reading and the percentage of error was 0.39% which is accepted. The percentage of accuracy of dose calibrator easily was detected by using accuracy equation. Concerning the precision test, which is a measure of the spread of values obtained from a sequence of measurements. These results showed high precision in dose calibrator. This Geometry test of dose calibrator was done by researcher to show that the calibrator is giving correct readings throughout the entire energy scale that he was likely to encounter. High energy standards (Cs-137 was measured in the dose calibrator using appropriate settings. Standard and measured values are compared. The results were in accepted.

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