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QUALITY CONTROL OF RADIONUCLIDE VDC-405 DOSE CALIBRATOR

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Abstract

Radiopharmaceuticals used in the Nuclear Medicine Department for diagnosis and therapeutic purposes are measured by dose calibrator system. Introducing of accurate dose of radionuclide is highly important for quality imaging as well as for treatment. Therefore, the quality control of dose calibrator is highly valuable for nuclear medicine imaging. This study is performed to assay the quality control and calibration of VDC-405 dose calibrator which is used to measure the activity of the radionuclide before administrating patient. Here the precision, accuracy, constancy and linearity of response have been measured for explaining correct operation of VDC-405. Error obtained within ±10% from constancy test and within ±5% from both precision and linearity test of TC-99m and I-131 which within acceptable limit. Therefore, it is concluded the dose calibrator VDC-405 using in cancer treatment for measuring activity of radionuclide is well functioning.

Keywords: Accuracy test, Linearity test, Dose calibrator, VDC-405.

Introduction

Quality control systems are important in many facilities. Because it ensures that the products from these facilities have a good and high standard. Radiopharmaceuticals are medical products, which contain a radioactive nucleus. Diagnosis or therapeutic use of radiopharmaceutical is totally dependent on the presence of the radioactive entity. In general the majority of radiopharmaceuticals is used for diagnosis. Therefore, the radiopharmaceutical preparations with short-lived radionuclides, such as ^{99m}Tc, ^{131}I, etc. require quality control test before administration to patient. Quality control is a process that is used to ensure a certain level of quality of a product (Abbas, 2013). In other words Quality control is the systems in your company that detects defects (Assan et al., 2012). Now shortly we describe dose calibrator as an ionization chamber used in nuclear

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medicine to measure the radioactivity of a radionuclide before injection into a patient (Jacobson et al., 2011). So quality control of dose calibrator means to ensure a certain level of radionuclide that can be injected into a patient without any harm. The activity of radionuclide is routinely used in nuclear medicine practice by dose calibrator to quantify the radioactivity dose of the radiopharmaceuticals to be administered to the patients. According to the current standards and regulations for nuclear medicine worldwide practices, including the international atomic energy agency and national regulations such as those manipulated by the United States Nuclear Regulatory Commission (U.S.N.R.C), 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 (Fred and Milton, 2000). Quality control of dose calibrator is very important because if over dose is exposed to patient then many biological problems will introduce. Such as short dose of up to 50 rem will probably cause no problems, except for some blood changes. From 50 to 200 rem may cause illness. A dose between 200 and 1,000 rem will most likely cause serious illness. Any dose over 1,000 rem will typically cause death (Patton et al., 1996). If the dose is lower than actual dose then we will not get the proper image. So we will not be able to diagnose the actual problem of the patient. So quality control is an essential part. 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 Constancy test of the instrument are important. Linearity means that the calibrator is able to indicate the correct activity over the range of use of that calibrator. This test is done using a vial or syringe of activity which is at least as large as the highest dosage that will be administered to a patient (Candelari and Irwin, 2010). This test is generally carried out by measuring a high activity of a short-lived radionuclide for a given period of time by the instrument. Typically, ^{99m}Tc, ^{131}I is used for this purpose. Accuracy test means to show that the calibrator is giving correct readings throughout the entire energy scale that is of our interest. Low, medium, and high energy standards are measured in the dose calibrator using appropriate settings. Standard and measured values are compared. Accuracy test is done on the time of installation and then annually. Constancy test measures precision and is designed to show that, using a long-lived source, usually reproducible readings are obtained day after day on all the various isotope settings that we want. The long-lived source is placed in the dose calibrator. Activity is then measured and all other routinely used settings on a daily basis. Values are recorded and put in the appropriate logbook and then compared with recent values to determine whether the instrument is maintaining constancy on a day-to-day basis or not (Lamk et al., 1990). The precision test for a wide range of radioisotopes showed that the precision for individual measured activities was well within ±5% for activities over 1 μCi. Even for very low activities (0.38 μCi) the precision was within ±10%. If quality control is not done then it may cause problems as follows:

I. Radiopharmaceuticals distribution in the body differs.

II. We will not get correct information in nuclear medicine study.

III. Problem will create in diagnostic interpretation.

IV. High background radioactivity due to the presence of radiochemical impurities observed that is harmfull.

V. The image quality will degrade.

VI. Patient will expose to unnecessary radiation.

Theory

This experiment was specifically based on the determination of radionuclides activity from the dose calibrator. The radionuclides used in our experiment were technesium-99 and Iodine - 131 respectively. For activity measurement, it is necessary to know the half-lives of the radionuclides.

Radioactive decay

Radioactive decay is the process in which an unstable atomic nucleus splits into smaller part and loses energy by emitting ionizing particles and radiation. This unstable atomic nucleus is called parent nuclide and decay or loss of energy, from the initial atom (Parent atom) results in another atom called the daughter nuclide. The prediction of decay of an unstable nucleus is really impossible. The radioactive decay is totally random. However, decay may be happened in any time. If N be the initial number of atoms then let at any time dt the radioactive decay be –dN. Then the probability of decay will be (-dN/N) is proportional to dt.

$$\text{Thus, } \frac{-dN}{N} = \lambda . dt$$

Particular radionuclides decay at different rates, each having its own decay constant (λ). The negative sign indicates that the initial number decreases with respect to time.

The solution of the differential equation is

$$N(t) = N_{0}e^{-\lambda t} \ldots\ldots(1)$$

Where, $[N_o]$ is the initial amount of atoms.

The differential decay constant λ has units of 1/time.

The half-life is related to the decay constant as follows:

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = T \ln 2 \ldots\ldots.(2)$$

This relationship shows that highly radioactive substances are quickly spent away. Half-lives of known radionuclides vary widely, from more than 10^{19} years to 10^{-23} seconds for highly unstable ones. The decay of the radioactive substance after a time t is

$$A_t = A_o e^{\left(\frac{-0.693t}{t_{\frac{1}{2}}}\right)} \ldots\ldots.(3)$$

A_t is the activity after time t, A_0 is the initial activity, t is the elapsed time and the half-life ($t_{1/2}$). The calculated activity and average activity reading should be within ±5.

For precision test the rules is

$$\left\{\frac{100(A_i - \tilde{A})}{\tilde{A}}\right\} \% \ldots\ldots\ldots\ldots\ldots.(4)$$

where A_i is the individual measured activity and $\tilde{A}$ is the mean activity.

For accuracy test the rule can be written as

$$\left\{\frac{100(\tilde{A} - C)}{\tilde{A}}\right\} \% \ldots \ldots . (5)$$

where $\tilde{A}$ is the mean activity and c is the certified activity of the source corrected for radioactive decay to the day of measurement.

C; calculated from equation

$$C = C_{0}e^{-\lambda t} \ldots\ldots\ldots\ldots.(6)$$

When

C_0 = Activity at Ref. Date

Methodology

Precision and Accuracy test

Thus include source holder, gamma-radiation source and remote handling device (forceps).

We first selected radionuclide that used in precision and accuracy test and set the dose calibrator in operating condition. The background reading was recorded and subtracted from measured activities. The radionuclide was kept in the forceps, placed in the source holder and inserted into the dose calibrator. We waited as much time as needed to obtain stable result. The activity was recorded and the background reading subtracted. The procedure was repeated several times at different heights (Zamani et al., 2008). Then the source holder was removed from the dose calibrator.

Linearity test of activity response

Thus include source holder, gamma-radiation source, remote handling device and lead shield

A solution of the radionuclide was eluted from the generator and kept in the sample vial. The vial was strongly capped and the operational conditions appropriately selected. We divided our Solution into three group i.e., with volume 4ml, 3ml and 2ml respectively (Rether and Merlo. 1990). The background reading was subtracted from our measured activities. The sample vial was inserted into the source holder by means of remote handling device and introduced into the dose calibrator. Sufficient time was allowed for the reading to stabilize and the background readings were subtracted from the measured activity. The exact time of the measurement was recorded. After all, the source holder was removed from the instrument. The procedure was repeated several times far greater than the half-life of the radionuclide we used.

Background response method

When no source was placed in the source holder of the dose calibrator then a low rate of emission of photon energy was obtained in our result. Background reading in activity units of the radionuclide concerned was recorded.

Reproducibility response method

The operating conditions appropriate to the radionuclide were selected. The background reading was recorded and subtracted from the measured activities. The radionuclide source was inserted into the source holder with the help of the remote handling device and introduced into the dose calibrator (Chilton and Witcofski, 1986). In order to stabilize the reading we allowed sufficient time. The background reading was subtracted from the measured activity. The source holder and source was removed from the dose. The procedure was repeated at several times at different heights.

Results and Discussion

Accuracy and Consistency test of dose calibrator

Accuracy and consistency tests were determined by using reference standard source e.g. ^{137}Cs. The activity of reference source was measured five times using dose calibrator and the results are shown in Table 1. The raw data were manipulated to obtain the average value for calculation of percentage of accuracy test as in equation 1.

Table 1. Show accuracy test by measured ^{137}Cs 5 times.

No.	^{137}Cs (μCi)	%SD
1	228	5.7
2	224	3.4
3	224	3.4
4	223	3.2
5	224	3.5
6	227	5.0
7	226	4.7
8	226	4.7
9	225	4.1
10	225	4.2
Average:	225.5	4.19

By using equation 5 and 6, we get

$$\text{Accuracy} = 4\%$$

The result shows ± 4% which is less than limited value. (± 10%) Therefore, it is confirmed that the dose calibrator is well performed in measuring radioactivity

Decay curve of dose calibrator

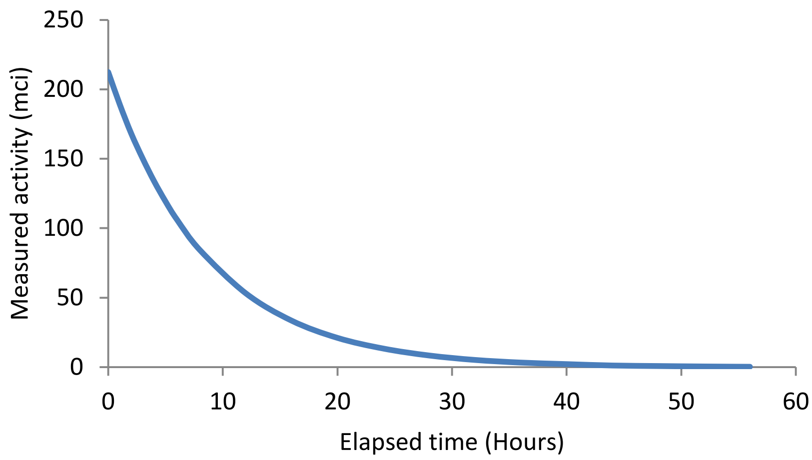

Fig. 1. Decay curve for ^{99m}Tc

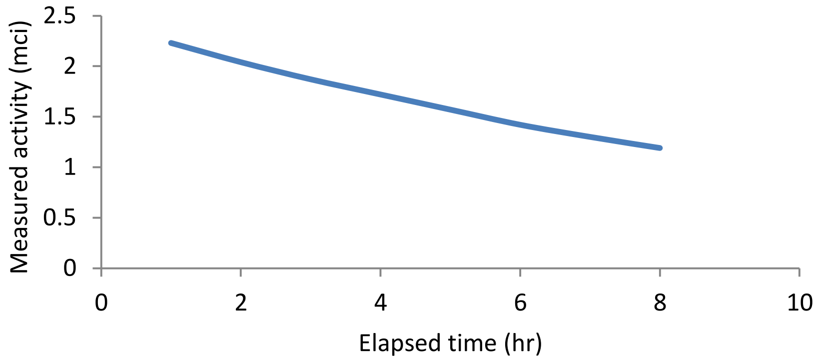

Fig. 2. Decay curve for ^{131}I.

From the decay curve of ^{99m}Tc and ^{131}I, we see that these curves are exactly same as the certified decay curve. For the Fig. 1, the decay curve is exactly follow the radioactive decay law as mentioned in equation (1). But for the case of Fig. 2 it didn't happen. This is because Iodine has a half life of 8 days but technetium has 6 hours. So it is hard to measure the accurate activity of Iodine after 8 days and the complete data collection time takes almost six months. So little variation is observed in the case of Iodine. Besides, Atomic energy Commission provides a very few amounts of Iodine in our divisional Hospital. Some background radiations may also affect the result. But was always calculated and subtracted.

Linearity test of dose calibrator

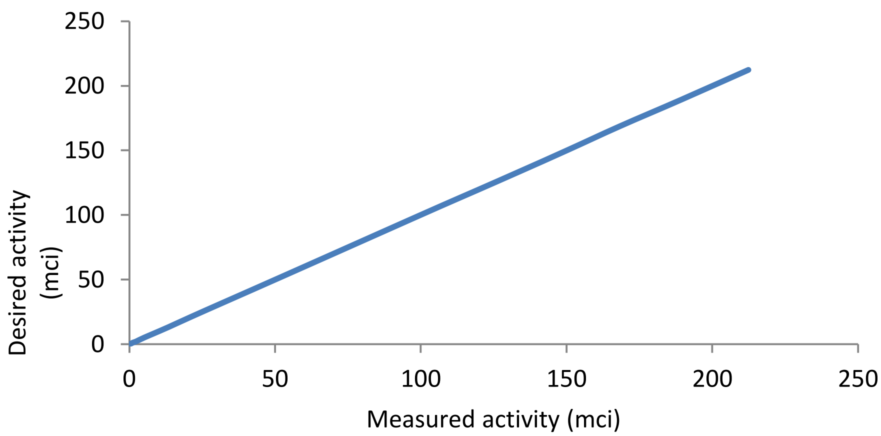

Fig. 3. Linearity curve of ^{99m}Tc.

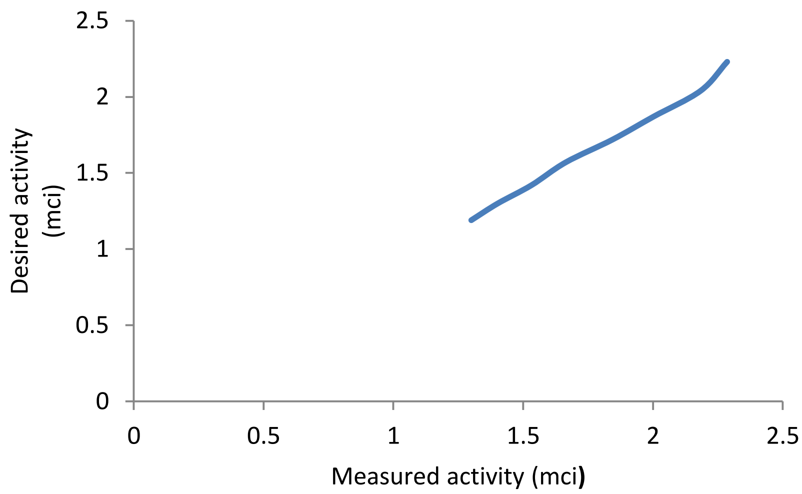

Fig. 4. Linearity curve of ^{131}I.

From the linearity test (Fig. 3 & 4), we get exactly the same result as predicted by the radioactive disintegration law. So we get the linear line which proves linearity test result. For the case of Iodine, the linear line didn't start from the beginning cause Iodine takes very long period of time to diminishes its activity to zero.

Precission test of Dose calibrator

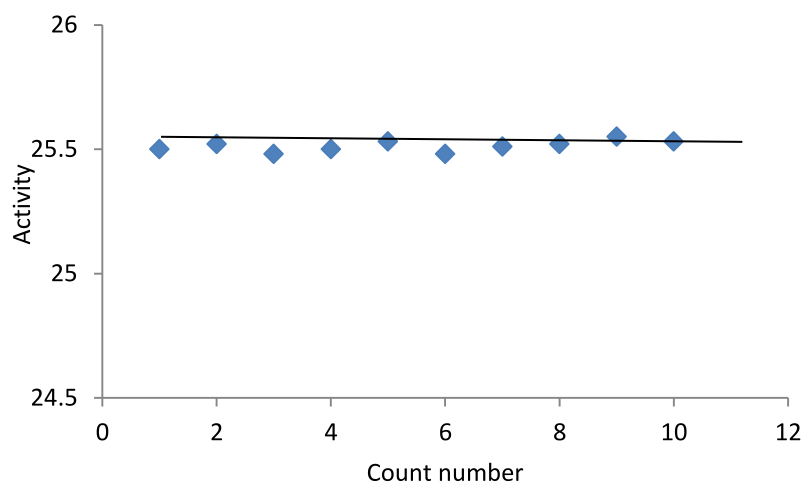

Fig. 5. Precision test graph using ^{99m}Tc.

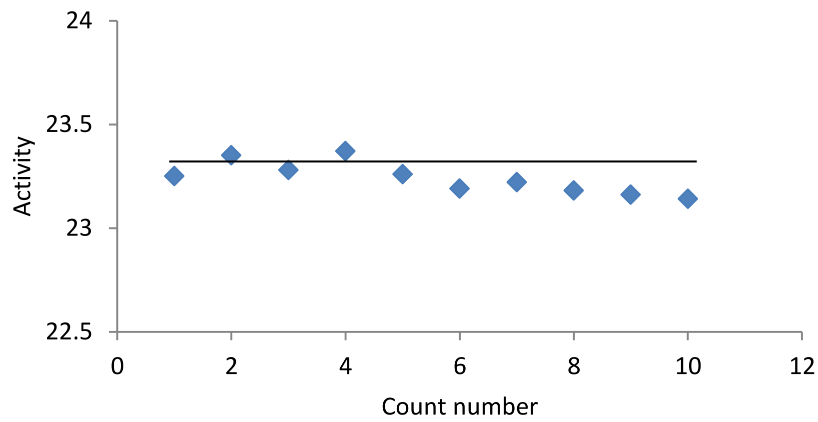

Fig. 6. Precision test graph using ^{131}I.

The precision test result (Fig. 5 & 6) indicates that, the dose calibrator used in our divisional Nuclear Medicine and Allied Sciences Institute is perfectly right.

Conclusion

Radioactive materials are widely used for therapeutic or diagnostic medical purposes.. In this case, the determination of the activity managed to the patient plays an important role for the success of therapy or the diagnostic procedure. Dose calibrator is a valuable tool for the assay of radioactive materials, but it is also important to understand their limitations. Therefore, quality control of dose calibrator should have done routinely for patient best care and good treatment. From accuracy, linearity and precision test we don't get any contamination. From the present study of accuracy, linearity and precision test get % of accuracy 4, linearity within ±10% and precision within ±5%. So we conclude that the quality control of dose calibrator VDC-405 used in the Institute of Nuclear Medicine & Allied Sciences is well functioning.

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