Full-range isotopic calibration of an RMS detector by F-18 decaying source method

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Abstract

An energy compensated G-M detector radiation monitoring system (RMS) has been calibrated by the decaying source method. The purpose of this isotopic calibration study is to investigate the G-M type dosimeter linearity at upper decades during high rate operations. An F-18 point source in ^{18}FDG format, with a half life of 109.74 min, is placed close to the detector to achieve a dose rate of about 2500 μSv/h that simulates a dead-time loss of about 20 percent based on vendor G-M detector specifications. The upper-decades calibration can be done in one day by consecutive measurements at every 20-min intervals. The detector dose-rate readouts, in one minute averaging, are recorded and calculated to be 386.2 +/- 5.2 μSv/h per mCi (37 MBq) after true source activities are decay-corrected and normalized. This environment RMS under investigation has shown a very good linearity response in upper three decades of better than 2% by this calibration run.

Keywords: Isotopic calibration, decaying source method, ^{18}FDG

Introduction

The purpose of this study is to calibrate the installed G-M dosimeter to be used in our whole body I-131 clearance rate research project involved with high dose rate operations. During high pulse rate operations, most of the RMS detectors would suffer nonlinearity response due to detector dead-time, signal pulse pile-up and others. With the modern digital RMS design in progress, the detector nonlinearity behaviour can be "straighten-out" by using software programming technique, for examples, such as the dead-time correction or the look-up table methods, etc. Several methods, like source-pulser method, decaying-source method, etc., have been proposed in the past for the dead-time measurements everywhere.[1,2]

Normally, an ambient RMS detector full-range calibration could be done either by using multiple standard sources set or by varying detector-to-source distances and attenuators to achieve per-decade calibration ranges needed. In our Nuclear Medicine PET/CT Centre, we are routinely receiving high specific F-18 sources (in ^{18}FDG format) in early morning for diagnostic imaging uses. Alternatively, these F-18 sources with a half-live value of 109.74 min can be chosen for the RMS detector linearity calibration purpose.

Materials and methods

In this investigation study, vendor-provided detector specifications include an energy-compensated G-M tube dead-time of 50 microseconds and a nominal sensitivity of 1000 cpm/mR/hr using a Cs-137 source. In order to simulate a 20% dead-time loss, a source activity has to be able to induce a dose rate at about 250 mR/h (2500 μSv/h) level at detector location. Based on photon flux calculation for a

250 mR/h dose rate, an initial F-18 activity of about 7 mCi is needed if a fixed source-to-detector distance is at about 12 cm.[3] The activity of the prepared F-18 source also has to be calibrated immediately by a certified ionization chamber dose calibrator. The isotope impurities are another major concern when a decaying method is in use that has to span across three decades range or more. We found that no impurity gamma peaks have shown up in the source spectrum for up to 24-hour decay (more than 10 times of F-18 half-lives) that was done earlier by a 2"x2" NaI(Tl) gamma spectroscopy system.

The RMS G-M detector is a wall-mounted device that is situated at 1 meter above the ground floor within our heavily shielded I-131 therapy ward. The RMS dose rate measurements are conducted by a remote display and control unit in our Nuclear Medicine Department (NMD) at a far away building. The I-131 ward is also equipped with several video cameras and their images are displayed on TV monitors located at our NMD office. The ambient radiation background in this ward is evaluated previously to be well below than 1 μSv/h by a certified hand-held pressurized ion chamber dose rate meter and shall have very little interference on the overall dose rate measurements during high rate operations.

We have an initial dose activity of 7.45 mCi (276 MBq) in 1 mL-volume of the F-18 (in ^{18}FDG format) liquid source being prepared and calibrated in a small plastic vial for use. This sealed source is then transferred and placed next to the RMS G-M detector at a distance of 12 cm by using a calibration fixture. This RMS provides the dose rate display in every second in a real-time basis. During the decaying source measurements, a preset one-minute dwell-time and a 1-min averaging data are automatic calculated at specific times of interest. In this experiment, we have chosen a 1-min averaging data taken for every 20-minute intervals in time sequential order during the entire high rate measurement tests.

Results and discussion

Only upper three decades have been checked for our current interest. We found it took a 20 minutes delay since the initial F-18 source is prepared, calibrated and installed at the calibration configuration within the I-131 ward. The first 1-min average dose rate is taken and shown at 2472 μSv/h (called time zero) that corresponds to a decay-corrected F-18 activity of 6.566 mCi. The subsequent detector calibration data were then acquired at specific times as shown in Table 1. After normalizing for the source decay-corrected activities, the average linearity response is then calculated to be 386.2 +/- 5.2 μSv/h (+/- 1σ) per mCi at the specific fixed geometry. The RMS detector under investigation has shown a very good linearity check in upper three decades of better than 2% by this calibration run.

Table 1. The RMS G-M detector isotopic calibration by decaying source method.

Data Recorded No.	Time elapsed (min)	1-min ave. dose rate readout (μSv/h)	Decay-corrected activities (mCi)	Normalized Dose rate readout (μSv/h per mCi)
1	0	2471.7	6.566	376.4
2	10	2321.5	6.164	376.6
3	30	2076.8	5.432	382.3
4	50	1845.3	4.788	385.4
5	70	1632.1	4.220	386.8
6	90	1440.8	3.719	387.4
7	110	1262.7	3.278	385.2
8	130	1132.8	2.888	392.2
9	150	992.2	2.546	389.7
10	170	868.4	2.244	387.0
11	190	772.9	1.977	390.9
12	310	359.8	0.9265	388.4
13	495	116.8	0.2973	392.8

Conclusions

Vendor-supplied RMS G-M detector has been calibrated by using a high specific ^{18}FDG point source in our shielded iodine therapy ward. This environment RMS under investigation has shown a very good linearity response in upper three decades of better than 2% by this calibration run. When a decaying-source method is adopted for the detector isotopic calibrations and linearity check, the ^{18}FDG has proved to be a convenience source of choice at most of the PET/CT clinics.

References

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