Department of Health
PUBLIC HEALTH SERVICES - RADIATION PROTECTION UNIT

Tasmanian Government

Recommended Quality Assurance Programme for Dose Calibrators

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First published April 2021
Next review April 2024

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Summary of Quality Assurance Requirements

This document provides recommendations to carry out the minimum quality assurance tests and performance criteria required for dose calibrators (also called radioisotope calibrators) in Tasmania. The recommended tests, their frequency and performance criteria are summarised in table 1 and are explained in more detail in various section of this document. Most of the testing can be performed by imaging technologists, however some tests (eg. accuracy) may require the contracting of third-party services.

Table 1: Recommended Quality Assurance tests for Dose Calibrators.

Test	Frequency[1]	Criteria
Routine QC tests	Daily	See Section 1
Constancy	Daily	The measured activity of the check source shall not differ from the calibrated activity by more than ±5%
Reproducability	Annually	Each individual measurement must not differ from the average measurement by more than ±1%
Accuracy	Annually	The average measured activity of the calibration source shall not differ from the certified activity by more than ±5% within the measurement uncertainty.
Linearity	Annually	The derived decay constant must not differ from the actual decay constant by more than ±5%

[1] Where the frequency of the test is daily, this refers to each day the scanner is in use.

1. Routine QC tests

Background

A set of routine QC test should be carried out on the dose calibrator daily before clinical used [1-4]. This will ensure that the calibrator is functioning as normal and is well maintained.

Procedure

- Physically inspect the dose calibrator, display screen, keypad and source dipper for damage. Check that the display screen is functioning properly.
- Perform a check of the system electronics with the manufacturers system test function if provided. This must also include a check of the high voltage setting.
- Check the accuracy of the system clock. The clock should be synchronised with system clocks on imaging equipment such as gamma cameras, SPECT/CT and PET/CT scanners. Clocks to be synchronised to one minute.
- Check for any external sources of background radiation as well as radioactive contamination of the dose calibrator and source dipper. Ensure all external sources are removed or shielded. Any radioactive contamination must be cleaned up and contaminated components (eg. source dipper) must be replaced.
- Check that the zero-adjustment function displays no activity when no sources are present.

After each inspection, the following must be recorded:

- Date of routing QC testing
- Model and serial number of dose calibrator
- Person performing routine QC testing
- Test results

2. Constancy

Background

The dose calibrator must be tested daily to ensure its reading remains constant over time [1-4]. This test checks the calibration settings of the dose calibrator as well the stability of the ionisation chamber and electronics. There are two types of constancy tests to perform:

Check source response:

Testing the calibration setting of a radioisotope by measuring a standard check source of that radioisotope (eg. Co-57 or Cs-137).

Relative response:

Testing the calibration setting of a clinically used radioisotope (eg. Tc-99m or F-18) by measuring a standard check source (eg. Co-57 or Cs-137).

Procedure

Check source response:

- Measure each check source in the dose calibrator using its own calibration setting. Record the activity measurement and the date and time of measurement.
- Remove the check source and record the background measurement, as well as the date and time.
- Repeat this check for at least one more check source.

Relative response:

- Measure one of the check sources using the calibration setting of a clinically used radioisotope. Record the activity measurement and the date and time of measurement.
- Remove the check source and record the background measurement, as well as the date and time.
- Repeat this check using calibration settings of all the clinically used radioisotopes

Analysis

- For each measurement of the check source, subtract any background reading from the measurement.
- Calculate the difference between the activity of the check source (decay corrected from the manufacture date) and the measured activity, expressed as a percentage of the calibrated activity.

Performance criteria

- The measured activity of the check source shall not differ from the calibrated activity by more than ±5%.

Corrective action

If the difference in the measured and calibrated activities of the check source is more than ±5%, consult the manufacturer of the dose calibrator for remedial action.

3. Reproducibility

Background

The reading of the dose calibrator must be reproducible over many measurements [1-3]. This ensures that the uncertainty in the measurement is primarily due to the random nature of radioactive decay.

Procedure

- Measure a long-lived radioisotope (eg. a Co-57 check source of 10 MBq) in the dose calibrator. Make 10 consecutive measurements about one minute apart, recording each measurement as you go.
- The background measurement should stay constant over the 10 measurements. If this is not the case, record the background measurement each time and use this to correct the readings.

Analysis

- Calculate the average of the 10 measurements.
- Calculate the difference between each of the 10 measurements and the average of the measurement, expressed as a percentage of the average measurement.

Performance criteria

- Each individual measurement must not differ from the average measurement by more than ±1%.

Corrective action

If any measurement differs from the average measurement by more than ±1%, consult the manufacturer of the dose calibrator for remedial action.

4. Accuracy

Background

This test is performed to ensure that the dose calibrator reading is accurate and is traceable to national or international standards of measurement [1-4]. The dose calibrator reading must be compared annually with the measurement standard.

Note: Calibration sources traceable to national primary and secondary standards of radioactivity are available from the Australian Nuclear Science and Technology Organisation (ANSTO) and from many suppliers of medical radioisotopes. A calibration certificate to certify traceability, including the calibrated activity and its uncertainty value, must be provided. It is preferable to obtain calibration sources of at least two clinically used radioisotopes (if more than one radioisotope is used) in the same container type and volume to that used clinically. Source activities must be greater than 10 MBq.

Procedure

- Measure the calibration source in the dose calibrator using the appropriate calibration setting. Record the measured activity, as well as the date and time.
- Remove the calibration source and record the background measurement, as well as the date and time.
- Repeat the activity measurement for a total of three measurements.
- Repeat the above steps for any other calibration source obtained.

Analysis

- For each calibration source measured, perform the necessary background corrections and average the three readings obtained. The measurement uncertainty is the standard deviation of the three measurements.
- Calculate the difference between the certified activity of the calibration source (decay corrected from the calibration date and time) and the average value of the measured activity, expressed as a percentage of the certified activity.

Performance criteria

- The average measured activity of the calibration source shall not differ from the certified activity by more than ±5%, within the measurement uncertainty.
- Upon a successful accuracy test, a sticker shall be affixed to the dose calibrator with the model and serial number of the dose calibrator, as well as the date that the next accuracy test is due.

Corrective action

If the difference in the measured and certified activities of the calibration source is more than ±5%, consult the manufacturer of the dose calibrator for remedial action; or derive a new calibrator factor in consultation with manufacturer.

5. Linearity

Background

The reading of the dose calibrator must be linear over the range that it is used for [1-4]. This ensures that it can be used to reliably measure the entire range of activities required for clinical practice. The equation describing radioactive decay of a source is:

$$A = A_0 e^{-\lambda t}$$

Where A is the activity of the source, A_0 is the initial activity of the source, t is the time elapsed from the initial measurement and λ is the decay constant (related to the half-life). The linear form of the above equation is obtained by taking the natural logarithm of both sides:

$$\ln(A) = \ln(A_0) - \lambda t$$

Therefore, by plotting the natural logarithm of the activity measurements against the time they were made, a straight line will be obtained. The negative slope of the line is equal to the decay constant.

Procedure

- Dispense a source of Tc-99m. The activity of the source should correspond to the maximum activity used clinically (eg. 1000 MBq). For dose calibrators used for PET, a 500 MBq source of F-18 can be used.
- Measure the source in the dose calibrator, correcting for background, and record the measurement as well as the date and time.
- Repeat the measurement at two-hour intervals throughout the day, recording each measurement. If using F-18, repeat the measurement every 30 minutes.
- Continue measurements on subsequent days until the source activity has decayed to 1 MBq.

Note: If the dose calibrator can be set up to automatically measure the source and log measurements at regular intervals, this method may be used.

Analysis

- Plot the natural logarithm of each activity measurement against the time elapsed from the initial measurement. The plot should be a straight line.
- Obtain the value of the slope of the line (the derived decay constant) and compare it to the appropriate decay constant in table 2 below.

Performance criteria

The derived decay constant must not differ from the theoretical decay constant(listed in Table 2) by more than ±5%.

Table 2 : Half-lives and decay constants of Tc-99m and F-18.

Radioisotope	Half-life (hr)	Decay constant (hr^{-1})
Tc-99m	6.01	0.115
F-18	1.83	0.379

Corrective action

If the difference in the derived and actual decay constants is more than ±5%, consult the manufacturer of the dose calibrator for remedial action.

Record keeping

The results of all regular QA testing must be recorded either in writing or electronically, and must be available for view by authorised officer when requested.

References

[1] International Atomic Energy Agency, *Quality Assurance for Radioactivity Measurements in Nuclear Medicine*, IAEA Technical Reports Series No. 454 (2006)

[2] European Association of Nuclear Medicine, *Routine Quality Control Recommendations for Nuclear Medicine Instrumentation*, Eur J Nucl Med Mol Imaging (2010) 37:662-671

[3] American Association of Physicists in Medicine, *The Selection, Use, Calibration and Quality Assurance of Radioisotope Calibrators Used in Nuclear Medicine,* AAPM Report No. 181 (2012)

[4] Australian Radiation Protection and Nuclear Safety Agency, *Safety Guide for Radiation Protection in Nuclear Medicine*, Radiation Protection Series Publication No. 14.2 (2008)