Computer-Based Quality Assurance Program for Dose Calibrators

Wayne R. Hedrick

Northeastern Ohio Universities College of Medicine, Rootstown, Ohio and Aultman Hospital, Canton, Ohio

A simple computerized reporting system for quality assurance testing of dose calibrators is described. The user enters the administrative parameters such as institutional header, dose calibrator descriptors, and reference source identifiers when the program is initially configured. These administrative parameters may be reviewed and changed as needed thereafter. The computer software allows for analysis of linearity (decay and shield method), accuracy, and geometry checks. Forms for recording daily constancy checks with the range of acceptable readings indicated for the respective radionuclide settings can be generated.

Evaluation of dose calibrator performance is an essential component of any quality assurance (QA) program in nuclear medicine (*1,2*). Proper performance is necessary for the accurate assessment of radiopharmaceutical activity prior to administration to the patient. The QA program must be simple to implement and easy to maintain. At the same time, the testing must be comprehensive to thoroughly evaluate the dose calibrator. The Nuclear Regulatory Commission (NRC) has established regulations which require testing (with appropriate documentation) of constancy, linearity, accuracy, and geometry (Table 1) (*3*).

Management of a QA program for the dose calibrator requires calculating current reference source activity, percent difference between expected and observed values, decay corrections, correction factors, etc.; recording institution, equipment, and reference source identifiers; creating forms to facilitate data collection; and generating reports. The computer is ideally suited to perform these tasks in a time-efficient manner. This article describes a computer program designed to assist in the implementation of a comprehensive QA program with minimal user interaction.

MATERIAL AND METHODS

The "Dose Calibrator Quality Assurance" (DOSCALQA) software is a collection of programs written in Microsoft advanced basic and is designed to run on an IBM XT, IBM AT, or IBM compatible computer. A dot matrix printer configured for the IBM standard character set is required to print the reports and forms. A hard disk drive is not required.

The software is menu driven, which allows the operator to select the desired task. The administrative parameters shown in Table 2 are stored in data files (total storage 2,130 bytes), which can be reviewed and changed as needed. The program utilizes this stored information to calculate the current activity of the respective reference sources and to print various descriptors required for documentation on the requested report. A description of the program methodology for the checks listed in Table 1 follows.

Daily Constancy Check

Daily constancy checks are designed to identify a loss of precision that can occur because of changes in background, modifications of shielding (the amount of scattered radiation is altered), long-term drift, or leakage of the counting gas. These checks are typically performed using a long-lived radioisotope such as cesium-137 (^{137}Cs). The usual method involves measuring the apparent activity of the reference source on various commonly used isotope settings and comparing these readings with those obtained previously for constancy. However, in order to assess small changes over a long period of time, a range of acceptable readings for each radionuclide setting must be established and periodically corrected for physical decay.

A ratio of the response or reading on a given radionuclide setting for the assay of a long-lived reference source with respect to the true activity of that reference source should be established for each commonly used radionuclide setting. Mathematically, the response ratio (R) is determined by:

$$R = \frac{\text{Activity reading}}{\text{Activity reference source}}. \qquad \text{Eq. 1}$$

This response ratio is constant for each radioisotope setting and should be determined during the initial calibration and following repair. The predicted reading of the reference source

For reprints contact: W.R. Hedrick, PhD, Aultman Hospital, 2600 Sixth St. SW, Canton, OH 44710.

TABLE 1. Quality Assurance Testing Required by the NRC

Check	Frequency	Documentation
Constancy	Each day of use	Model and serial number of dose calibrator Radionuclide Date Activity measured Initials of individual performing check
Linearity	Upon installation Following repair Quarterly	Model and serial number of dose calibrator Calculated activities Measured activities Date Signature of RSO
Accuracy	Upon installation Following repair Annually	Model and serial number of dose calibrator Model and serial number of each reference source Radionuclide Activity of each reference source Measured activity of each reference source Signature of RSO
Geometry	Upon installation Following repair	Model and serial number of dose calibrator Configuration of source Activity measured for each volume Date Signature of RSO

assayed at a later date on a particular radionuclide setting can be calculated using the response ratio (R) and the calibrated activity of the reference source (A_o) corrected for decay:

$$\text{Predicted Reading} = RA_o\, e^{-\lambda t}, \qquad \text{Eq. 2}$$

where λ is the decay constant of the reference source and t is the elapsed time between the date of calibration of the reference source and the date of measurement. A range of acceptable readings for each radionuclide setting is established as 0.95 to 1.05 times the predicted reading.

In practice a reference source such as cobalt-57 (^{57}Co) can also be used for the daily constant checks. Since a ^{57}Co source loses ~ 7% of its activity during a month, corrections must be made for radioactive decay. The usual method consists of graphing the acceptable range of the measured activity as a function of time based on calculated endpoints (such as the first day of each month). The graphing method was developed to eliminate the time consuming process of calculating decay corrections for each day of the month. However, the computer can readily perform these calculations, which allows an acceptable range to be determined for each day of the month. This enables the individual performing the constancy check to record the measurement, to determine if observed value is within the listed acceptable range, and to initial the results.

TABLE 2. Contents of Data Files

File	Stored parameters
Institution	Variable number of lines established by user (40 characters/line)
Dose calibrator	Manufacturer Model Serial number
Reference sources	Isotope Half-life Calibration activity Date of calibration Manufacturer Model Serial Number
Response ratios (^{137}Cs)	Radionuclide setting Value of response ratio
Response ratios (^{57}Co)	Radionuclide setting Value of response ratio
Linearity lead sleeve	Sleeve descriptor Sleeve factor
Radiation Safety Officer	Name and title (40 characters)

No graphing of these data is required, which saves personnel time.

A response ratio also can be defined for the ^{57}Co reference source in the same manner as described previously for the long-lived reference sources (see Eq. 1). The response ratio for the ^{57}Co also is constant for each radioisotope setting and can be used to predict the reading at a future date using Eq. 2.

The DOSCALQA program requires the user to input the month and year of interest. A form for recording the daily constancy checks in accordance with NRC regulations is then printed. The acceptable range for a reference source assayed on each user-designated radionuclide setting is indicated.

Linearity (Decay Method)

The purpose of the linearity check is to evaluate the ability of the dose calibrator to measure the correct activity over a wide range of activities. The decay method utilizes a vial of technetium-99, which is repeatedly assayed over a period of a few days.

The usual method to analyze the linearity data consists of plotting the measured activity as a function of time on a semilogarithmic graph and comparing these points with a straight line with a slope equivalent to 6 hr. However, the ability to ascertain 5% deviations from the predicted straight line plot is very difficult.

A tabular format listing the measured activity and the corresponding predicted activity at a particular time provides a more rapid and accurate comparison of these data.

The DOSCALQA program requires the user to input the measured activity as well as the day and time of the measurement. The report, which contains an analysis of the linearity in a tabular format as well as the information required by the NRC, is printed at the completion of data entry.

TABLE 3. Response Ratios for Various Radionuclide Settings Using ^{57}Co and ^{137}Cs Reference Sources

Radionuclide setting	^{57}Co response ratio* average (±SD)	^{137}Cs response ratio† average (±SD)
^{99m}Tc	1.18 (0.01)	1.82 (0.01)
^{131}I	0.831 (0.010)	1.28 (0.01)
^{123}I	0.545 (0.004)	0.847 (0.004)
^{133}Xe	0.720 (0.001)	1.11 (0.01)
^{67}Ga	1.06 (0.02)	1.65 (0.02)
^{201}Tl	0.677 (0.005)	1.05 (0.01)
^{111}In	0.502 (0.018)	0.781 (0.02)

* Average values from four dose calibrators at different institutions.
† Average values from six dose calibrators at different institutions.

Linearity (Shield Method)

The shield method utilizes a set of lead sleeves of different thicknesses that are designed to attenuate the gamma radiation. By sequentially placing an increased thickness of the attenuator around the source assayed in the dose calibrator, radioactive decay can be simulated. Each lead sleeve must be individually calibrated to correspond to a time of decay (t) and, hence, to a reduction factor (RF) given by:

$$\mathrm{RF(sleeve)} = e^{\lambda t} = \frac{\text{Reading (no sleeve)}}{\text{Reading (sleeve)}}, \qquad \text{Eq. 3}$$

where λ is the decay constant of source. The respective reduction factors for the set of lead sleeves are constant for a specific dose calibrator.

The DOSCALQA program requires the user to input the measured activity for each lead sleeve whose descriptor and reduction factor have already been entered as administrative parameters. Each measured activity is automatically corrected by the appropriate reduction factor, and the resulting activities are examined for variation. A report containing the information required by the NRC is printed at the completion of data entry.

TABLE 4. Description of Computer Generated-Documents

Check	User input	Output
Constancy	Month and year	Month and year Day of month Radionuclide settings Acceptable range for each radionuclide setting Model and serial number of dose calibrator Columns for recording observed readings of reference source Column for initials of individual performing check
Linearity (decay method)	Day and time of measurement Measured activity	Institutional header Date Day and time of measurement Measured activity Calculated activity Percent difference between expected and observed values Model and serial number of dose calibrator RSO name
Linearity (shield method)	Measured activity for each sleeve	Institutional header Date Sleeve used Reduction factor for each sleeve Predicted activity for each sleeve Statement of variation Model and serial number of dose calibrator RSO name
Accuracy	Select reference sources from current listing Measured activity for each source	Institutional header Date Radionuclides Predicted activities Measured activities Percent difference between expected and observed values Calibration activity, calibration date, manufacturer, model, and serial number of reference sources Model and serial number of dose calibrator Statement of variation RSO name
Geometry	Source configuration Measured activity for each volume	Institutional header Source configuration Date Measured activity for various volumes Model and serial number of dose calibrator Correction factors if variation exceeds 10% RSO name

NUCLEAR MEDICINE SERVICE
AULTMAN HOSPITAL
CANTON, OHIO

ACCURACY CHECK

DATE: 06/09/88

SOURCE	PREDICTED ACTIVITY	MEASURED ACTIVITY	PERCENT DIFFERENCE
^{137}Cs	170 μCi	170 μCi	0.28
^{57}Co	2.378 mCi	2.310 mCi	−2.84

REFERENCE SOURCES

SOURCE	ACT (μCi)	CAL DATE	MFR.	MODEL	SERIAL NO.
^{137}Cs	209	05/07/79	NEN	356	3560579A38
^{57}Co	4890	09/01/87	AMERSHAM	CTCV1	7372A

DOSE CALIBRATOR IDENTIFICATION
MANUFACTURER: SEARLE
MODEL: CRC 22NB
SERIAL NUMBER: 33551

All measured values are within ± 5% of the predicted activities.

DATE: ________ Reviewed by: ____________________
W.R. HEDRICK, Ph.D.
Radiation Safety Officer

FIG. 1. Example of accuracy check report.

Accuracy

For a given reference source the measured activity should agree with the certified activity (corrected for radioactive decay) within 5%. The reference source should have a calibration that is traceable to the National Bureau of Standards. In order to evaluate the energy response of the dose calibrator, separate reference sources with different energy photon emissions should be utilized. The NRC presently requires two different radionuclides (one of which must have principal photon emissions between 100 keV and 500 keV) for the accuracy check.

The DOSCALQA program requires the user to identify the reference source from the current listing and to input the activity measured for each source. The present activity of the respective reference sources is automatically calculated and compared with the measured activity by computing the percent difference. A report containing the information required by the NRC is printed at the completion of data entry.

Geometry

The ionization chamber is designed to minimize the effects of small variations in sample position and volume. Nevertheless, the change in indicated activity as a function of source configuration and volume must be assessed and correction factors generated if the variation exceeds 10%. Typically, the geometry check is performed by obtaining activity readings as a function of volume for a syringe or vial containing a source of constant activity.

The DOSCALQA program requires the user to identify the source configuration and to input the activity measured for each volume. The geometric variation is automatically calculated at the completion of data entry. If the geometric variation is <10%, then a report consisting of the entered data and a statement that the variation is <10% is printed for review by the RSO. If the geometric variation exceeds 10%, then a correction factor (CF) for each volume is computed by calculating the ratio of the measured activity to the reference volume activity (designated by the user):

$$\text{CF (Volume)} = \frac{\text{Measured activity (volume)}}{\text{Measured activity (reference volume)}}. \quad \text{Eq. 4}$$

A report listing the correction factor for each volume is printed for review by the Radiation Safety Officer (RSO).

RESULTS AND DISCUSSION

Cesium-137 and ^{57}Co response ratios for several radioisotope settings obtained from dose calibrators at different institutions are listed in Table 3. However, the response ratios for a specific dose calibrator must be measured for that instrument. The data in Table 3 are presented as a guide.

The required user input and the generated output for each check are summarized in Table 4. Entry of the administrative parameters shown in Table 2 is not required for each execution of the program since this information is permanently available in the data files.

As an example, a report of an accuracy check is reproduced in Figure 1. A total of 18 keystrokes were required to generate this report.

The DOSCALQA software simplifies the task of evaluating the quality assurance checks for the dose calibrator and produces the required NRC reports. Since the administrative parameters are saved in data files, the user is not required to enter this information each time the program is executed. The use of this software results in a considerable reduction in technologist/physicist time required to perform dose calibrator QA checks. The source codes are provided for easy modification by those desiring to do so.

Editor's Note: DOSCALQA is available free of charge from the author. The interested user can send the author a self-addressed stamped "floppy" mailer with a DOS 2.n (or DOS 3.n for the AT) formatted 5¼ in. floppy disk.

REFERENCES

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