Dose Calibrator Activity Linearity Evaluations With ALARA Exposures

Daniel A. Davis, Charles A. Giomuso, William H. Miller, John R. Ferrell, Paul J. Early, Vincent A. Gargaro, Frank T. Bloe, David W. Close, and Edward J. Began

Nuclear Medicine Associates, Inc., Cleveland, Ohio

The current procedure for demonstrating dose calibrator activity linearity requires that a series of readings be acquired throughout the range of activities to be assayed by the instrument. The Nuclear Regulatory Commission recommends this technique be accomplished by assaying the first elution from an Mo-99/Tc-99m generator over a period of several days. To reduce exposure, cost, time, and material, we propose an alternate method, which uses a series of lead tubes with each placed sequentially around the source in the dose calibrator to simulate decay. The benefits of this technique are that the source does not have to be removed from the dose calibrator; the radiation exposure to personnel is maintained as low as reasonably achievable (ALARA); the evaluation can be performed in a few minutes; and the source can subsequently be used for kit preparation or patient dose administration.

In accordance with the U.S. Nuclear Regulatory Commission's Regulatory Guide 10.8-27, Guide For The Preparation Of Applications For Medical Programs, (and in accordance with many states' regulations), "The linearity of a dose calibrator should be ascertained over the entire range of activities employed. This test will use a vial of Tc-99m whose activity is equivalent to the maximum anticipated activity to be assayed." Typically, the procedure calls for the decay of a Tc-99m source over a 2- to 3-day period. The activities displayed on the dose calibrator are compared to calculated activities remaining at the same times. One may graph the results on semi-logarithmic paper and compare the curve to a theoretical decay curve. Current regulations require that the displayed values must fall within ±5% of the calculated values. The decay method will identify a linear or non-linear instrument, but it has several disadvantages—including multiple radiation exposures to personnel during source handling, the additional cost for the test source, and sometimes personnel errors occur, which require the procedure to be repeated.

In order to establish procedures in accordance with the ALARA concept, we propose an alternate method of performing an activity linearity check on a dose calibrator with minimal source handling. Use of this alternate procedure may require approval of the agency issuing the radioactive materials license.

Materials and Methods

Seven tubes were assembled, six of which were provided with varying thicknesses of lead. Each leaded tube had an inside diameter large enough to allow it to slide over the seventh, unleaded tube. The outside diameter of each leaded tube was small enough to allow easy insertion into the dose calibrator. All were long enough to extend above the top of the dose calibrator chamber to allow easy insertion and removal.

Each leaded tube was color coded to correlate to a different thickness of lead wrap. The thickness of lead selected for each tube was chosen so as to offer shielding simulating the decay that would have occurred had measurements been made at various times from approximately 2 hr to 48 hr after an initial assay. The seventh unshielded central tube was used to provide a constant geometry for either a syringe or vial (Fig. 1).

Procedure

The linearity test kit was initially devised and calibrated using a dose calibrator pretested by conventional methods and determined to be linear in response to various activities placed in the chamber. A shielding factor for each leaded tube was then calculated by placing the source inside each tube and relating the activity displayed from a source of Tc-99m inside the tube to the activity displayed with the same source without

For reprints contact: William H. Miller, Nuclear Medicine Associates, Inc., 9726 Park Heights, Cleveland, OH 44125.

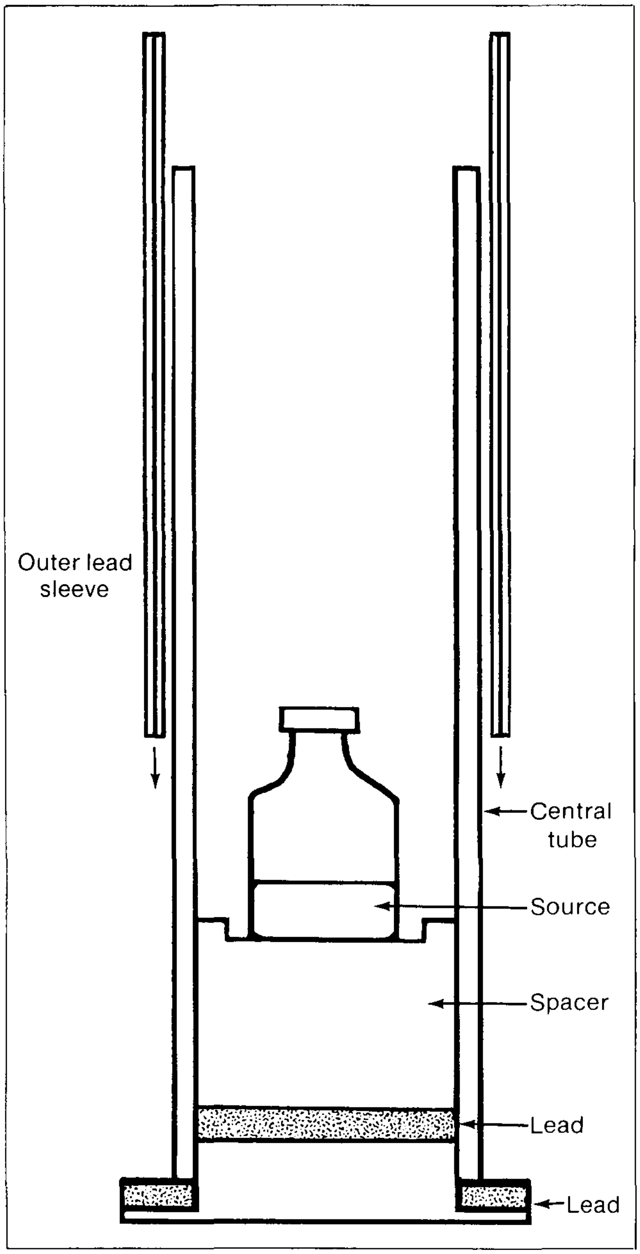

FIG. 1. Source vial rests on spacer within central tube. Outer lead sleeve slides down to lead base of central tube, closing cylinder.

TABLE 1. Shielding Technique: Activity Linearity Data Analysis

A	B	C	D	E
Tube numbers	Displayed activity (mCi)	1/measured shielding factor*	Normalized value	Per cent error
0	200	1.00	200	-0.3%
0 + 1	155	1.28	198	-1.3%
0 + 2	63.5	3.15	200	-0.3%
0 + 3	25.2	8.06	203	+1.1%
0 + 4	7.1	28.50	202	+0.6%
0 + 5	2.61	78.10	203	+1.1%
0 + 6	0.893	238.00	199	-1.0%
			Mean: 200.7	

*Factors were determined for each tube using a source of Tc-99m in a vial geometry in a specific manufacturer's dose calibrator. Variations in source geometry or dose calibrator may alter factors.

the leaded tube. The derived values were expressed as a per cent of transmission. These values were inverted, identified as a shielding factor, and entered in Table 1 (column C), for use in subsequent linearity evaluations. Over the next few weeks, several linearity evaluations were performed to test for dose calibrator stability. An example of results obtained from one test is found in Table 1 (column B).

To perform the linearity test, a source of Tc-99m representing the maximum amount of activity likely to be assayed over the course of a calendar quarter, was transferred into the unshielded tube (Table 1, tube no. 0). Proper handling techniques were observed, i.e., use of long handled forceps, etc. After removing the dose calibrator's syringe holder and "zeroing" the unit, the unshielded tube containing the source was placed into the center of the chamber. The source was not removed for the duration of the activity linearity check. The displayed activity was recorded representing maximum activity at zero time.

To simulate decay of the Tc-99m source, the color-coded tubes were then sequentially placed over the center tube. The first lead-lined tube (Table 1, tube no. 1), bearing enough lead wrap to attenuate radiation from the source to simulate a 2-hr decay of Tc-99m, was placed over the central tube and allowed to slide down until it gently came to rest on the base of the central tube assembly. Any gamma radiation that did not pass through the leaded tube was prevented from reaching the ionization chamber by the kit's design (Fig. 1). A second reading was then recorded. Tube no. 1 was then removed and replaced with the second lead-lined tube, which bore enough lead wrap to simulate approximately a 9-hr decay of Tc-99m. A reading was taken and recorded.

The second tube was then removed and replaced in succession by tube numbers 3,4,5, and 6. The decreasing displayed values were recorded on a worksheet as in Table 1, column B.

Data were analyzed in the following manner. Each of the displayed activities taken from the dose calibrator was multiplied by the reciprocal of the shielding factor found for each tube (Table 1, column C) and the results entered as a normalized value (Table 1, column D). The mean of the normalized values was multiplied by 1.05 and 0.95. These products represent the acceptable upper and lower limits. If all the values in column D fell between the calculated ±5% limits, the dose calibrator was functioning properly. If one or more of the values were to fall outside the ±5% limits, the test would be repeated to rule out statistical variations and technical errors (e.g., improper rezeroing). Consistent results outside the normal range would reflect a malfunctioning dose calibrator. In such a case, the dose calibrator would have to be repaired or recalibrated.

The data entered in Table 1, column E, represents the deviation from the mean of the normalized values in the case cited. Similar results were obtained using varying amounts of activity and same amounts of activity at different times.

Summary

We investigated an alternate method of performing dose calibrator activity linearity checks. A shielding concept was used in order to construct six coded, lead-wrapped tubes. These tubes were used to simulate up to, approximately, a 48-hr decay of Tc-99m. Test results indicated that the activity linearity response of a dose calibrator can be determined without serial dilutions or decay of a radioactive source. Because a test source is handled less using this technique, exposure to nuclear medicine personnel may be reduced; thus, it accords with the ALARA concept. The time required to conduct the entire test is approximately 3–5 min. Results can be verified in the same time frame; whereas using the decay method, at least 48 hr would elapse. Also, the entire Tc-99m test source (eluent or single dose) is reusable for kit and patient dose.

The data obtained from our experiments using this shielding technique demonstrated constant and reproducible results for a designated geometry and dose calibrator.

Acknowledgment

This work was presented at the 28th Annual Meeting of the Society of Nuclear Medicine, Las Vegas, Nevada, June 1981.