A Quality Assurance Survey of Scintillation Cameras and Dose Calibrators

Donald R. Hamilton and Clifford D. Evans

National Center for Devices and Radiological Health, Rockville, Maryland

A survey of nuclear medicine quality assurance practices was conducted by the National Center for Devices and Radiological Health as part of the Center's overall efforts to improve quality assurance in each of the disciplines of medical imaging. The data show fragmentary acceptance of quality assurance practices for scintillation cameras and radionuclide dose calibrators. A strong educational effort is needed in order to increase the awareness and acceptance of an inclusive quality assurance program.

The National Center for Devices and Radiological Health (NCDRH) began a nuclear medicine quality assurance survey in 1978 as part of an overall effort to improve quality assurance in each discipline within medical imaging. This survey of nuclear medicine facilities was viewed as a means of accomplishing two major objectives: ascertaining the acceptance of existing recommendations for quality assurance in nuclear medicine; and evaluating the effectiveness of NCDRH's educational programs. We present data on the initial results of the survey program.

Methods and Materials

The survey was planned to encompass the quality assurance of scintillation cameras and dose calibrators. It began with the collection of demographic information about the participating facilities and data about their quality assurance programs for scintillation cameras and dose calibrators. The survey was performed in 1980 at 321 selected facilities in 15 states (Alabama, Arkansas, California, Colorado, Idaho, Illinois, Louisiana, Maine, Mississippi, New Hampshire, New Jersey, North Dakota, Oregon, Rhode Island, and Washington) by personnel from the state radiation control programs. This represents approximately 10% of the nation's nuclear medicine facilities.

Facilities to be surveyed were chosen to coincide with routine compliance inspections. This survey was accomplished through the use of uniform three-part questionnaires, standard test protocols, and data evaluation techniques.

The first section of the questionnaire asked about demographic factors and about the types of personnel in the nuclear medicine department. The second section contained questions about the radionuclide dose calibrator and the quality assurance program in place for checking its operation. The third section posed similar questions regarding scintillation cameras.

The facilities' dose calibrators were checked with several different radionuclide standards to determine their accuracy over a wide range of gamma energies.

To provide technical assistance to the surveyors, NCDRH developed and field tested the questionnaire and related forms. Standard sets of test equipment were assembled and distributed to the participating states. These sets consisted of four calibrated reference sources (Co-57, Co-60, Ba-133, Cs-137) for checking the dose calibrators, a large field flood source (Co-57), and four different test patterns ($\frac{3}{16}$ in. orthogonal hole, $\frac{1}{8}$ in. parallel line equal space (PLES), $\frac{3}{16}$ in. PLES, and a $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, and $\frac{3}{8}$ in. 90° bar quadrant) to be used for checking the operation of the scintillation camera. A two-day training program was presented in Rockville, MD, to familiarize the surveyors with the project and the survey questionnaire.

Results and Discussion

Demographic Information: The vast majority of nuclear medicine procedures (97.5%) were performed in hospitals with the remainder performed in clinics and private offices. The average hospital in the surveyed population had 229.4 beds and performed an average of 1,819 procedures in 1979, with 599 (32.9%) being performed on an outpatient basis. The nuclear medicine department was surveyed directly in 54.4% of the responding facilities. Nuclear medicine procedures were performed in either the radiology or pathology departments in 44.0% of the surveyed facilities.

On the average 2.63 physicians were responsible for nuclear medicine activities in each of the surveyed facilities. The average physician had 10.1 years of experience, served a residency training in radiology, was board certified in radiology, and spent 50.9% of his or her time within the surveyed department.

There was an average of 2.41 nuclear medicine technologists per surveyed facility. The average technologist had spent 5.8 years in nuclear medicine, had formalized training in either nuclear medicine or diagnostic x-ray, was board certified, and spent 82.1% of his or her time in the department. Eighty percent of the technologists were certified by at least one of the voluntary certification boards. The percentage of diagnostic x-ray technologists who are certified is approximately 43.0% (*1*). The American Registry of Radiologic Technologists had certified 33.5% of the surveyed technologists and 29.1% were certified by both ARRT and the Nuclear Medicine Technology Certification Board.

None of the surveyed facilities employed a nuclear pharmacist. Therefore, the surveyed facilities had radiopharmaceuticals supplied to them by the manufacturer or a commercial radiopharmacy, or a nuclear medicine technologist in the facil-

ity took care of its radiopharmaceutical requirements.

While both the Nuclear Regulatory Commission (NRC) and the Agreement States require a facility to have at least consultant coverage by a medical physicist (2), in 54.2% of the surveyed facilities there was no such coverage.

In 87.8% of the surveyed facilities, a physician acted as the radiation safety officer. In surveyed facilities that employed a medical physicist, only 17.7% of these physicists functioned as the radiation safety officer.

Dose Calibrators: There were 332 dose calibrators surveyed in the 321 facilities. Capintec manufactured 65.2% of the surveyed dose calibrators. Picker, Searle, and RADX manufactured approximately the same number of surveyed dose calibrators (7.5 to 10.5%), and several other manufacturers had smaller percentages of the surveyed market.

The average dose calibrator downtime was 2.0 days per year. The majority of surveyed dose calibrators were not covered by a maintenance contract.

Cesium-137 was the most frequently used radionuclide for calibration (81.9%), with Co-57 also used frequently (55.1%). Cobalt-60 and Ba-133 were only used on about 20% of the surveyed dose calibrators.

Technetium-99m was the most frequent routinely assayed radionuclide (99.4%) with Mo-99, Ga-67, and I-131 also being assayed on a majority of the surveyed dose calibrators. Several other radionuclides were routinely assayed to a much lesser extent.

Information was also collected on the specific quality assurance procedures used for dose calibrators (accuracy, constancy, geometry, linearity, and relative response). Quality assurance testing for all the above except relative response is required by the NRC. The specific requirements can be found in NRC Guide 10.8, Appendix D (2).

Accuracy is a measure of how closely an assay of a standardized radionuclide compares with the actual standardized activity. The preferred method of accuracy measurement has recently been stated in a standard adopted by the American National Standards Institutes (ANSI) (3). Accuracy should be tested on an annual basis and every time the dose calibrator has been serviced. Of the surveyed dose calibrators, 60.1% were in compliance with this requirement (Table 1).

Constancy involves the routine monitoring of the operational consistency of a dose calibrator and should be performed daily. This monitoring ensures that the dose calibrator is operating in the same manner day after day, and that the original calibration is still valid. A preferred method for constancy testing has also been adopted by ANSI (3). Of the surveyed dose calibrators, 77.2% were in compliance with this requirement (Table 1).

Geometry may influence the accuracy of the readings obtained with the dose calibrators. The size, shape, and material of the container for the radioactive sample may influence the measurement of the activity because of self-attenuation and attenuation by the container. The position of the sample within the cavity of the ionization chamber also may affect the reading. The influence of geometry should be tested when the dose calibrator is installed and whenever a container of new shape or different composition is used for the first time. Those facilities that reported performing a quality control test for geometry on a daily or weekly basis (1.8%) probably did not understand geometry testing (Table 1).

Linearity tests whether the dose calibrator reading is directly proportional to the amount of radioactivity being assayed. Ideally, the dose calibrator will respond linearly over a range of activity from a few microcuries to several curies. There is sometimes an inaccurate response in the higher ranges, where the reading may be lower than the true activity. Linearity testing should be performed on a quarterly basis. Of the surveyed dose calibrators, 36.7% were in compliance for this quality control test (Table 1).

Relative response testing determines the functioning of the dose calibrator by taking measurements with a long-lived radionuclide (e.g., Cs-137) at each of the dose calibrator settings. A ratio of responses or reading per millicurie of a given radionuclide with respect to a long-lived reference source is established at each dose calibrator setting. This ratio, a constant for each instrument that is determined during the initial calibration, can be used to calculate the activity of a sample of that radionuclide from paired measurements with the same reference source (corrected for decay) (4). Although not required, it should be performed on a quarterly basis. Relative response testing was performed on 35.8% of the surveyed dose calibrators (Table 1).

The surveyed dose calibrators were also checked with four different radionuclide standards in order to determine their accuracy over a wide range of gamma energies. NRC Guideline 10.8, Appendix D (2) states that a dose calibrator's measured activity of a standard must be within ±5% of the true activity of that standard, after correction for radioactive decay.

The majority of dose calibrators tested were within the accuracy limits dictated by the NRC (Table 2). The data in the last column, number of dose calibrators, differ for each of the radionuclides because not all dose calibrators had either a preset button for each of the measured radionuclides or a fast method

TABLE 1. Frequency of Quality Assurance Tests For Dose Calibrators*

	Daily	Weekly	Monthly	Quarterly	Semi-annually	Annually	Not performed	Total
Accuracy	22 (6.6)	5 (1.5)	5 (1.5)	38 (11.4)	22 (6.6)	108 (32.5)	132 (39.9)	332 (100.0)
Precision	256 (77.2)	31 (9.3)	1 (0.3)	6 (1.8)	3 (0.9)	3 (0.9)	32 (9.6)	332 (100.0)
Geometry	4 (1.2)	2 (0.6)	0	23 (6.9)	16 (4.8)	56 (16.9)	231 (69.6)	332 (100.0)
Linearity	1 (0.3)	5 (1.5)	11 (3.3)	105 (31.6)	30 (9.0)	52 (15.7)	128 (38.6)	332 (100.0)
Relative response	64 (19.3)	5 (1.5)	1 (0.3)	19 (5.7)	3 (0.9)	27 (8.1)	213 (64.2)	332 (100.0)

*Numbers in parentheses indicate percentages.

TABLE 2. Dose Calibrator Measurement Data

Radionuclide	Mean Difference (%)	Standard deviation (%)	Number of dose calibrators
Cobalt-57	−2.31	6.21	268
Barium-133	−1.76	5.50	214
Cesium-137	1.25	4.20	298
Cobalt-60	−3.11	5.05	244

of correctly setting the potentiometer to assay that particular radionuclide accurately.

Scintillation Cameras: There were 395 scintillation cameras in the 321 surveyed facilities. Siemens manufactured 42.8% of the scintillation cameras in the surveyed facilities. Picker, Technicare, and General Electric were three other commonly found scintillation cameras with a few scintillation cameras of each of several other manufacturers reported.

The average scintillation camera downtime was 4.2 days per year. Of the surveyed scintillation cameras, 56.5% had maintenance contracts. This indicates either that scintillation cameras do not function at the same high level of assumed reliability as dose calibrators, or that the higher cost of repairs for scintillation cameras necessitates the contracts.

Information was collected on the specific quality assurance procedures for scintillation cameras (uniformity, spatial resolution, and spatial distortion). Although NRC has no regulatory requirements for quality assurance testing of scintillation cameras, NCDRH has published recommendations for these tests (5). Additionally, the Joint Commission on Accreditation of Hospitals (JCAH) states that for a facility to be accredited it must perform the appropriate quality control tests on all equipment each day the equipment is used (6).

Uniformity testing is a measurement of the ability of a scintillation camera to reproduce with fidelity an image of a uniformly distributed radioactive source. It is recommended that uniformity testing be performed daily. Of the surveyed scinitllation cameras, 88.5% were in accordance with this recommendation (Table 3).

Spatial resolution testing measures the ability of a scintillation camera to image two separate point or line sources of radioactivity as separate entities. It is recommended that spatial resolution testing be performed daily. Of the surveyed scintillation cameras, 29.1% were in accordance with this recommendation (Table 3).

Spatial distortion testing measures the ability of a scintilla-

tion camera to reproduce arrays of linear sources of radioactivity in such a manner as to conserve all the spatial and geometric relationships of the array. It is recommended that spatial distortion testing be performed daily. Of the surveyed scintillation cameras, 28.9% were in accordance with this recommendation (Table 3).

Only 66.5% of the surveyed scintillation cameras had a written log of the photopeak or CRT intensity or both maintained by the surveyed facilities. A log should be maintained to provide indications of changes in the imaging system.

Point sources were used 48.4% of the time on the surveyed scintillation cameras to test for uniformity, and the 90° bar quadrant phantom was used 69.6% of the time to test for spatial resolution and spatial distortion.

Quality control images from only 47.3% of the surveyed scintillation cameras were displayed with patient images for the interpreting physician. It is very important for the physician to have these quality control images if he is to accurately interpret the patient's clinical images.

Only 32.2% of the surveyed scintillation cameras utilized a computer for quality assurance. Of those scintillation cameras that did utilize a computer, 74.0% did so for data analysis and 70.1% did so for field uniformity correction.

Some of the surveyed scintillation cameras used a uniformity correction/autopeaking module. This module was limited to scintillation cameras manufactured by General Electric, Picker, Technicare, and Raytheon. The other manufacturers did not use this device at the time of the survey. Of the surveyed scintillation cameras by these manufacturers (208), 89.4% use the uniformity correction/autopeaking module.

Conclusion

There were two major objectives of this survey. The first was to determine the acceptance of existing recommendations for quality assurance in nuclear medicine. The data we collected show a fragmentary acceptance of quality assurance practices for scintillation cameras and dose calibrators.

The second objective was to evaluate the effectiveness of NCDRH's educational programs. The results show that a strong educational effort is needed in order to increase the awareness and acceptance of an inclusive quality assurance program. This educational effort will use currently available material, including workshops, publications, and exhibits.

After the completion of this educational endeavor and a re-survey of the original population, NCDRH will be able to determine the impact of its educational efforts and voluntary

TABLE 3. Frequency of Quality Assurance Tests For Scintillation Cameras*

	Daily		3× weekly		2× weekly		Weekly		Monthly		Quarterly		Semi-annually		Annually		Not performed		Total	
Uniformity	350	(88.5)	3	(0.8)	26	(6.6)	2	(0.5)	2	(0.5)	0		0		0		10	(2.5)	395	(100.0)
Spatial resolution	115	(29.1)	2	(0.5)	6	(1.5)	149	(37.8)	27	(6.8)	28	(7.1)	4	(1.0)	4	(1.0)	60	(15.2)	395	(100.0)
Spatial distortion	114	(28.9)	2	(0.5)	5	(1.3)	138	(34.9)	26	(6.6)	28	(7.1)	4	(1.0)	4	(1.0)	74	(18.7)	395	(100.0)

*Numbers in parentheses indicate percentages.

recommendations by the improvement in nuclear medicine quality assurance practices.

————

The complete publication on which this article is based, *Joint NCDRH and State Quality Assurance Surveys in Nuclear Medicine: Phase 1—Scintillation Cameras and Dose Calibrators*, is available from Superintendent of Documents, US Government Printing Office, Washington, DC 20402. FDA 83-8209, GPO 017-015-00214-4 $3.75.

References

1. Consumer-patient radiation health and safety act of 1981. Congressional Record–Senate, March 6, 1981.

2. US Nuclear Regulatory Commission. NRC Regulatory Guide 10.8, Revision 1. Guide for the preparation of applications for medical programs, Appendix D. Methods for calibration of dose calibrators. US Nuclear Regulatory Commission, Washington, DC, 1980.

3. Institute of Electrical and Electronics Engineers. Calibration and usage of "dose calibrator" ionization chamber for the assay of radionuclides, ANSI N42.13, IEEE Inc., New York 1978.

4. Hauser W, Cavallo L. Measurement and quality assurance of the amount of administered tracer. In: *Quality control in nuclear medicine*. Rhodes BA, ed., St. Louis: CV Mosby, 1977, 154–63.

5. US Department of Health, Education and Welfare. Quality control of scintillation cameras. HEW Publication FDA 76-8046, 1976.

6. Joint Commission on Accreditation of Hospitals. Nuclear Medicine Services, Accreditation Manual for Hospitals. Chicago, 1983.