Quality Assurance of Scintillation Cameras: An Implementation Program

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With the sophistication and increased use of scintillation cameras in nuclear medicine, routine quality assurance procedures are needed to insure a consistent and acceptable level of performance. A set of simple protocols has been developed to facilitate use of these procedures in a daily quality assurance program. To implement application of the protocols, a workshop on quality assurance for scintillation cameras has been developed for presentation to clinical nuclear medicine personnel. The Scintillation Camera Quality Assurance Workshop has been presented in eight locations, and information for the presentation of a workshop is available for nationwide distribution.

In nuclear medicine, the interpretation of static images and dynamic function studies often depends critically on the quality of the images and data furnished by the equipment and techniques used. This critical dependence exists because abnormal conditions in the patient frequently are manifested as subtle changes in the images and data that are barely above the threshold of detectability. Suboptimal equipment and techniques may cause these subtle changes to fall below the threshold of detectability and therefore pass unnoticed by the physician. For this reason, it is essential that nuclear medicine equipment and procedures be maintained at an acceptable level of performance at all times. To achieve this objective, a continuous program of quality assurance is needed in each medical institution with nuclear medicine facilities.

Various advisory and regulatory agencies for nuclear medicine services have recognized the importance of quality assurance procedures in nuclear medicine by requiring that adequate testing procedures be performed and recorded regularly as conditions for accreditation and licensure. For example, the Joint Commission on Accreditation of Hospitals (JCAH) has published the following standard for hospital nuclear medicine services *(1)*.

> Standard III: There shall be quality control procedures governing nuclear medicine services that insure diagnostic reliability and patient safety.

The JCAH interpretation of this standard includes:

> Instrument calibration procedures, sufficient to affirm proper performance, shall be conducted each day the instrument is used, and the results recorded.

Licensure standards of the United States Public Health Service (USPHS) for clinical laboratories require *(2)*:

> Quality control imposed and practiced by the laboratory must provide for and assure preventive maintenance, periodic inspection or testing for proper operation of equipment and instruments.

For radiobioassay, the required quality control procedures include:

> The counting equipment shall be checked for stability at least once on each day of use, with radioactive standards or reference sources.

Regulations of the Social Security Administration related to services of independent laboratories under the Health Insurance for the Aged program have been amended to require adherence to the USPHS Clinical Laboratory Licensure standards *(3)*. Although these standards currently apply primarily to in vitro procedures, extension of the

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standards to in vivo procedures certainly is possible, if not probable.

Implementation of quality assurance practices in nuclear medicine has been encouraged by a number of professional and regulatory organizations, including the American Association of Physicists in in Medicine, American National Standards Institute, Bureau of Radiological Health, College of American Pathologists, Society of Nuclear Medicine, United States Nuclear Regulatory Commission, and most state agencies responsible for radiation control. Although this encouragement has helped identify the need for quality assurance programs in nuclear medicine, little effort has been directed toward the delineation of adequate programs, and no specific schedule has evolved for the administration of quality assurance programs in a clinical nuclear medicine facility. Furthermore, little effort has been directed toward development of an implementation mechanism to encourage adoption of quality assurance procedures in clinical nuclear medicine facilities around the country. To address these problems, a program was initiated in Denver about a year ago to develop quality assurance protocols for specific nuclear medicine procedures and, through a series of implementation-oriented workshops, to encourage application of the protocols to clinical nuclear medicine facilities in the Rocky Mountain region. With the assistance of the Bureau of Radiological Health, the geographic region to be served by the workshops has been expanded to the entire country. This nationwide program is the topic of the remainder of this paper.

Quality Assurance Protocols

In the approach described here for development of a quality assurance program for nuclear medicine facilities, clinical nuclear medicine activities have been grouped into categories amenable to specific quality assurance protocols. The first five categories and their priority rankings are:

1. Scintillation camera quality assurance.
2. Radioisotope handling and control procedures, and isotope calibration quality assurance.
3. Rectilinear scanner, uptake units, etc., quality assurance.
4. Radiopharmaceutical quality assurance.
5. Radioimmunoassay and in vitro tests, instrumentation and quality assurance.

At the present time, protocols have been developed and tested for scintillation camera quality assurance, and an implementation program has been designed which involves a number of workshops to be held in strategic locations around the country. These protocols and workshops are described later. Similar protocols have been developed for isotope calibrators, and procedures for radioisotope handling and radiopharmaceutical quality assurance are currently being designed and evaluated. Workshops on scintillation camera quality assurance have been held in Denver, Cincinnati, Albuquerque, Phoenix, Cheyenne, Fort Worth, Memphis, and Puerto Rico and workshops in other locations are planned for 1975. Workshops on radioisotope handling and radiopharmaceutical and isotope calibrator quality assurance were held in Cheyenne, Denver, and Colorado Springs in February and March 1975. These regional workshops facilitate the evolution of the quality assurance protocols and workshop format prior to their distribution over a wider geographic region. This evolution has occurred for the scintillation camera quality assurance protocols and workshops, and this portion of the quality assurance program is ready for widespread distribution.

As an example of the approach to design and implementation of quality assurance protocols intended for this project, the scintillation camera quality assurance program will be discussed here in a rather brief fashion. Discussion in greater detail is available in a manual of about 100 pages which is distributed to each participant in the scintillation camera quality assurance workshops. Discussed in the manual are topics such as: Introduction to Quality Assurance of Scintillation Cameras, Evaluation of Scintillation Camera Performance, History and Evolution of the Scintillation Camera, Introduction to Scintillation Camera Operation, Daily Quality Assurance Tests Flow Sheet, Apparatus for Quality Assurance Procedures, Image Recording Media for Scintillation Cameras, Preparation Guide for a ^{57}Co Flood Phantom, Construction Guide for a Parallel Line Equal Spacing (PLES) Phantom, and Protocols for Quality Assurance Procedures for Specific Scintillation Cameras.

Evaluation of every aspect of the performance of a scintillation camera can be a complex process which requires the use of sophisticated test equipment and time-consuming test procedures. Due to the time and technical skill required, an analysis of this scope is not practical as a routine procedure for monitoring camera performance. For daily evaluation of camera performance by the nuclear medicine technologist, test procedures are needed which are relatively simple and quick to perform and analyze. These procedures should provide a general index of the quality of camera operation rather than an explicit identification of malfunctioning components. We have considered many tests of scintillation camera performance

which contribute in some way to a general overview of camera performance and have concluded that tests of three parameters furnish an adequate index in most cases. These parameters are:

1. Uniformity: the ability of the camera to produce an image of uniform density when the radioactive source provides a uniform distribution of gamma rays across the face of the detector.
2. Linearity: the ability of the camera to produce an image of straight lines when the radioactive material is distributed as straight lines in the source.
3. Resolving power: the ability of the camera to display in the image two regions of radioactivity which are separated by a short distance in the source.

An evaluation of these parameters composes the main thrust of the scintillation camera quality assurance program.

For the evaluation of uniformity, linearity, and resolving power of a typical scintillation camera only two items are needed. These two items are a source of radiation and a resolving power phantom. The radiation source should emit gamma rays with an energy matched closely to that from the radionuclide used for most clinical studies. Usually, the major clinical radionuclide is ^{99m}Tc, and a test source of ^{99m}Tc (140 keV), ^{57}Co (122 keV), or conceivably, ^{153}Gd (103 keV), is satisfactory for the quality assurance procedures. The source may be either a point source (e.g., a sealed ^{57}Co source or a spent syringe containing ^{99m}Tc residue) or a disk source (e.g., a hollow thin cylinder containing a ^{57}Co or ^{99m}Tc solution or a solid plastic disk containing ^{57}Co). Precautions required in the construction and use of radiation sources of different geometries and composition are described in the workshop manual.

For evaluation of uniformity, an image of 1,000K counts is compiled with the source in a prescribed position (on the collimator or detector for a disk source or at least 4 ft away with the collimator removed for a point source), and the image is evaluated for obvious nonuniformity. Uniformity variations below about 10% are probably not clinically significant *(4)*.

For assessment of linearity and resolving power, a transmission-type resolving power phantom is recommended for use in combination with the point or disk source. Commercially available phantoms which are satisfactory for this assessment include the 90° bar quadrant phantom and the Hine-Duley® phantom. These phantoms have certain limitations which are overcome to some extent by a different phantom design referred to as a parallel-line, equal-spacing (PLES) phantom *(5)*. The PLES phantom is not available commercially, however, and must be constructed locally with lead bar width and spacing selected for the camera with which it will be used. Instructions for constructing a PLES phantom are included in the workshop manual. For evaluation of camera linearity and resolving power, the transmission-type resolving power phantom is interposed between the radiation source and the camera face, and an image of at least 500K counts is obtained. Linearity and resolving power are evaluated by study of the image.

Procedures for evaluation of uniformity, linearity, and resolving power have been described in a set of cookbook-like protocols which are written for specific models of scintillation cameras. These protocols are designed for implementation on different cameras with a minimum of difficulty and time, and include test procedures such as techniques to distinguish nonuniformities caused by irregularities in the cathode-ray display device from those introduced by photomultiplier tube imbalance or the photographic film and processing conditions.

TYPICAL SCHEDULE FOR SCINTILLATION CAMERA QUALITY ASSURANCE WORKSHOPS

First Day	
10 min	Introduction and Review of Workshop Program
20 min	Objectives of Quality Assurance in Nuclear Medicine
20 min	History of Scintillation Cameras
40 min	Signal Processing in Scintillation Cameras
45 min	Quality Assurance Procedures and Protocols
30 min	Review of Uniformity, Linearity, and Resolving Power Images
30 min	Evaluation of Camera Quality Assurance Testing Results on Typical Cameras
1 hr	Basic Troubleshooting Procedures
Second Day	
30 min	Organization and Discussion of Morning Activities
3 hr	Demonstration and Performance of Quality Assurance Test Procedures on Scintillation Cameras in Local Hospitals
1 hr, 45 min	Discussion of Camera Quality Assurance Testing Results

Workshop Program

For adequate review of all procedures for scintillation camera quality assurance, a two-day

teaching format is followed as outlined in the box on the previous page.

The first afternoon's program consists primarily of a review of material contained in the workshop manual, copies of which are distributed at the beginning of the workshop. Included in this program is an exhibit of quality assurance test results which demonstrates uniformity, linearity, and resolving power images obtained from a number of different cameras. Workshop participants are asked to rank these cameras from best to worst in each performance parameter. The following day these ratings are compared with those obtained in previous workshops.

The next morning, workshop participants convene for a brief orientation to the morning's activities before separating into groups of six to eight persons for "hands-on" experience in conducting the quality assurance procedures on cameras similar to those in their own institutions. For this part of the workshop, cameras are reserved in hospitals near the site of the program. Each participant is asked to perform the quality assurance protocols under the supervision of one of the workshop faculty, usually in combination with a technologist from the participating hospital. Problems and questions in conducting these protocols are discussed either at this time or later during the discussion period. Each person who participates in the entire workshop receives a certificate of workshop participation.

Alternatives to this two-day schedule are possible. The workshop may be conducted in a single day, for example, although this schedule usually is not recommended because it is too busy to permit proper discussion and interchange of ideas. Time for discussion and review of specific problems can be added at the end of the second morning session, and the workshop faculty can remain behind after the workshop has officially ended for additional discussion with interested participants.

Administration of the workshop is the responsibility of a local workshop director selected for his knowledge of clinical nuclear medicine and for his interest in the quality assurance program. This selection is made in consultation with officers of the Technologist Section of the Society of Nuclear Medicine. The workshop director is responsible for announcing the workshop, for securing physical facilities for the first afternoon and second morning programs, and for suggesting faculty for all parts of the workshop. In these activities, he is assisted by R. Van Tuinen who will, if necessary, visit the workshop location for a couple of days 4 weeks or so before the workshop. Since the workshop manuals and quality assurance protocols are essentially self-explanatory, solicitation of faculty should not be unduly difficult. Nevertheless, persons are available if needed outside a particular geographic region.

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