CHAPTER
15

Quality Assurance in Nuclear Medicine

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OBJECTIVES

At the completion of this chapter the reader will be able to do the following:

- Describe the principles of radiation detection and measurement
- Describe the scintillation crystal
- Describe the basic principles of the gamma camera
- Describe the scintillation camera performance characteristics of image linearity, image uniformity, intrinsic spatial resolution, detection efficiency, and counting rate problems
- Describe the design and performance characteristics of commonly used collimators
- Describe planar camera quality control testing methods of calibration, gamma energy spectrum, window determination, daily floods (intrinsic and extrinsic), weekly resolution (intrinsic and extrinsic), counting efficiency and sensitivity, and multiwindow spatial registration

- Describe gamma camera single-photon emission computerized tomography (SPECT) systems
- Describe SPECT quality control (i.e., flood uniformity, center of rotation, attenuation correction, and pixel size)
- Describe positron emission tomography and its quality control
- Describe nuclear medicine nonimaging equipment and related quality control procedures (i.e., gas-filled detectors such as dose calibrators, survey meters, Geiger-Müller (GM) meters, and scintillation detectors such as the multichannel analyzer and thyroid probe)
- Describe quality control procedures in a radiopharmacy and radionuclide generator quality control evaluation of contaminant such as molybdenum, aluminum, and hydrolyzed reduced technetium

Nuclear medicine technology is a scientific and clinical discipline involving the diagnostic, therapeutic, and investigative use of radionuclides. The nuclear medicine professional performs a variety of responsibilities in a typical day including formulating, dispensing, and administering radiopharmaceuticals; performing in vivo and in vitro laboratory procedures; acquiring, processing, and analyzing patient studies on a computer; performing all daily equipment testing; preparing the patient for the studies; operating the imaging and nonimaging equipment; and maintaining a radiation safety program. Because of the variety of responsibilities in the nuclear medicine department, **The Joint Commission** (TJC) has recognized the necessity for an established quality assurance program in nuclear medicine. TJC states that "There shall be quality control policies and procedures governing nuclear medicine activities that assure diagnostic and therapeutic reliability and safety of the patients and personnel (Accreditation manual for hospitals, 1993)." The **American College of Radiology** (ACR) also offers accreditation of nuclear medicine departments and mandates that certain quality assurance procedures be performed. This chapter discusses the many quality assurance procedures routinely performed in nuclear medicine. In the summer of 2008, Congress passed the Medicare Improvements for Patients and Providers Act of 2008 (MIPPA), which mandates that any nonhospital institution performing advanced diagnostic services (such as nuclear medicine and PET) must be accredited (by January 1, 2010) in order to receive federal funding (Medicare reimbursement). The CARE bill (discussed in Chapter 1) if passed, would make similar requirements for hospital-based facilities; therefore, accreditation programs are becoming mandatory for nuclear medicine departments to succeed.

THE SCINTILLATION GAMMA CAMERA

The scintillation **gamma camera** was first developed by Hal Anger in 1958 and has undergone many changes in design and electrical sophistication since its inception.

However, the basic components of the gamma camera remain the same (Fig. 15-1) (Anger, 1958). The camera consists of a circular or rectangular detector mounted on a gantry, which allows flexible manipulation around a patient, and electronic processing and display components. In addition, the camera system is interfaced to a computer to control study acquisition, analysis, and display. The detector head contains a thallium-activated sodium iodide (NaI[T1]) crystal, **photomultiplier tubes** (PMTs), preamplifiers, a position energy circuit, a pulse height analyzer, and a display mechanism.

Because radiation is a random process, gamma rays are not easy to control. The energy of the ionizing gamma radiation is too high to be deflected like visible light. However, the gamma **photon** can be directed through holes in a **collimator** while it blocks tangential or
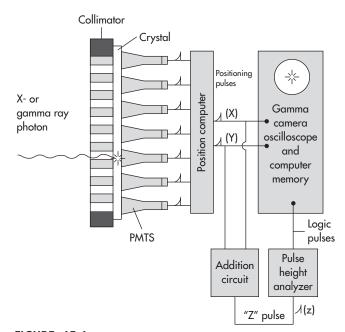
FIGURE 15-1 Basic scintillation camera detector components. *PMTS,* photomultiplier tubes. *(From Thrall JH, Ziessman HA: Nuclear medicine: the requisites, St Louis, 1995, Mosby.)*
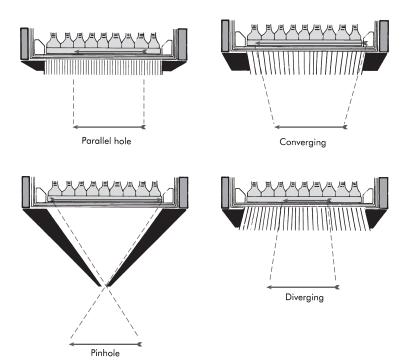
FIGURE 15-2 Four common types of collimators used on gamma cameras. *(From Bernier DR, Christian PE, Langan JM:* Nuclear medicine: technology and techniques, *ed 3, St Louis 1994, Mosby.)*

scattered photons. For a resolving image to be obtained, the collimator must be placed on the face of the detector head; this placement allows the desirable gamma photons to pass through to the NaI(T1) crystal. A collimator is a lead-filtering device that consists of holes through which a gamma photon can pass. These holes are separated by lead septa (Fig. 15-2). The photons that are not absorbed or scattered by the lead septa pass straight through to the NaI(T1) crystal and subsequently create an image of the isotope distribution from the patient. With high-energy photons, thicker lead septa are required to prevent scatter from degrading the image.

Collimators are available from several manufacturers. The collimator chosen for a patient study depends on the isotope energy and resolution required for the specific diagnostic procedure. Collimators commonly used in nuclear medicine include low-, medium-, and high-energy parallel hole; high-resolution parallel hole; high-sensitivity parallel hole; general all-purpose parallel hole; pinhole; and converging and diverging collimators (Early and Sodee, 1995). Because collimators are made specifically to operate within a gamma photon's energy range, a nuclear medicine department must have collimators suitable for several types of applications. The most common type used for diagnostic studies is the parallel-hole collimator. The parallel-hole collimator is preferred because it directs photons from a patient onto the scintillation crystal without varying the image. Once the photon passes through the collimator, it reaches the NaI(T1) **scintillation crystal** and is converted to light. The number of light photons produced is directly proportional to the energy of the gamma photon. Typically, 30 photons are produced

per kiloelectron volt (keV) of energy (Murray and Ell, 1994). The NaI(T1) crystals vary in diameter, shape, and thickness. Changing the parameters of the crystal affects sensitivity or resolution (i.e., if sensitivity is increased by the use of a thicker crystal, then the resolution is compromised and vice versa). The NaI(T1) crystal is hygroscopic and extremely sensitive to sudden temperature changes. The environment of the gamma camera must remain stable, and precautions must be taken to prevent moisture from entering the NaI(T1) crystal and sudden temperature shifts (Early and Sodee, 1995). In addition, an accidental impact may cause the crystal to crack.

The scintillation, or light, photon interacts with the PMT. The light generated in the NaI(T1) crystal is then converted to electrical signals. The electrons produced are amplified and accelerated a millionfold in the PMT system. After conversion to an electrical pulse, a position circuit produces X and Y position signals, which are directly related to the location of the photon interaction on the NaI(T1) crystal. Because of the high potential of ionizing radiation interacting with matter, not all of the gamma photons detected by the NaI(T1) crystal are the original primary gamma photons of interest. The interactions with matter from the patient and through the camera system can cause scatter radiation. Too much scatter radiation can cause degradation in the resolution of the final image. It is therefore possible to electronically exclude undesirable photons by only accepting the gamma ray photons above a certain energy.

The discrimination and selection of the gamma photon are performed with a **pulse height analyzer** (PHA). The PHA can be preset to accept only specific energy