in echocardiography should be the responsibility of the director of the echocardiographic training laboratory and the director of the cardiology training program.

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Task Force 5: Training in Nuclear Cardiology*

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Training in Nuclear Cardiology

Nuclear cardiology methods (Table 1) provide important diagnostic and prognostic information with which all modern cardiologists should be conversant. Training for cardiology fellows should be divided into three levels:†

1. *General training* (2 months) for all cardiology fellows is designed to make the fellow conversant with the field of nuclear cardiology (level 1).
2. *Specialized training* (4 to 6 months) for fellows who wish to have special expertise in clinical nuclear cardiology and practice nuclear cardiology (level 2).
3. *Advanced training* (1 year) for trainees who wish to pursue an academic direction in nuclear cardiology, including patient care, teaching and research (level 3).

Training should include the study of the indications for specific nuclear cardiology tests and proper clinical application of the diagnostic information derived from the appropriate

*The recommendations of this task force were developed jointly with the American Society of Nuclear Cardiology and will be published in the *Journal of Nuclear Cardiology*. These recommendations were approved by the Board of Directors of the Society.

†The issues of ongoing clinical competence and training or retraining of practicing cardiologists are beyond the scope of this document. However, it should be noted that these issues are currently being addressed by the American Society of Nuclear Cardiology (ASNC). For additional information, contact ASNC at 9111 Old Georgetown Road, Bethesda, Maryland 20814.

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test. Independent interpretation of nuclear studies, followed by integration of test results with other clinical and laboratory data, is desirable. This training should be acquired in an Accreditation Council for Graduate Medical Education (ACGME) approved program in either cardiology, nuclear medicine or radiology. The preceptor should ensure that a logbook or other specific records document cases and didactic training hours in which the fellow has participated. In the case of the advanced trainee, specialized training and research can be derived as a part of an established program either in cardiology or in a division of nuclear medicine; the preceptor for specialized or advanced training should have level 3 (or the equivalent) training in nuclear cardiology.

General Training—Level 1 (2-Month Minimum)

The trainee should be exposed to the fundamentals of nuclear cardiology for a period of two months during the fellowship. This two month experience should provide exposure to nuclear medicine technology and practice sufficient for the clinical practice of adult cardiology, but not for the practice of nuclear cardiology.

Background. To have an adequate understanding of the clinical applications of nuclear cardiology and to perform the test safely, the physician trainee must acquire knowledge of or proficiency in, or both, the following areas:

1. Coronary angiography and dynamics
2. Cardiac hemodynamics
3. Cardiac pathophysiology
4. Rest and exercise electrocardiography
5. Exercise physiology
6. Pharmacology of standard cardiovascular drugs
7. Cardiopulmonary resuscitation and treatment of other cardiac emergencies
8. Pharmacology and physiology of commonly used stress agents, such as dipyridamole, adenosine and dobutamine
9. Clinical outcomes assessment

Didactic program. *Interpretation of radionuclide studies.* During their 2-month rotation, fellows should actively participate in daily radionuclide study interpretation (minimum of 80 h) under the direction of a qualified individual in nuclear cardiology. For all studies in which angiographic or hemodynamic data, or both, are available, such information should be correlated with the radionuclide studies. Studies should include one or more of the following:

1. *Myocardial (perfusion) imaging* with exercise and redistribution, rest or reinjection studies, or both, or pharmacologic stress using qualitative and quantitative analysis.
2. *Radionuclide angiography* using the gated equilibrium or "first-pass" approach, or both.
3. An established teaching file of both perfusion and ventricular function studies with angiographic/cardiac catheterization documentation of disease should be available in each program.

Ideally, experience in all of these aspects of nuclear cardiology is recommended. Nevertheless, in institutions that emphasize certain procedures, an adequate background for general fellowship training in nuclear cardiology can be satisfied with less diversified training.

Lectures and reading in nuclear cardiology. The second component of the didactic program should consist of lectures on the basic aspects of nuclear cardiology and parallel reading material. The lectures and reading should provide the fellow with an outline of the applications of nuclear cardiology, including positron emission tomography (PET). Specificity, sensitivity, diagnostic accuracy, utility in assessing prognosis and interventions, costs, indications and pitfalls must be emphasized for each patient subset. Such information could be effectively transmitted within a weekly noninvasive conference or catheterization conference during which the radionuclide imaging data are presented.

Knowledge and appreciation of radiation safety. The third component of the didactic program should provide the fellow with an appreciation of radiation safety as it relates to administration of radiopharmaceuticals.

Hands-on experience. Fellows should perform complete nuclear cardiology studies alongside the qualified technologist or other qualified personnel. They should observe and then participate under qualified supervision in the following procedures: preparation, calibration and administration of the radiopharmaceutical dose; treadmill, bicycle and pharmacologic stress testing, alone or in combination; utilization of the electrocardiographic gating device; basic operation and quality control of the gamma camera; operation of the imaging computer system for acquisition, image processing and appropriate display. This should include adequate experience in stress myocardial perfusion, radionuclide angiography (rest or exercise, or both; equilibrium or "first pass," or both); and miscellaneous procedures.

Specialized Training—Level 2 (4 to 6 Months)

Fellows who wish to *practice the specialty of clinical nuclear cardiology* should be required to have at least 4 to 6 months of total training. In training institutions with a high volume of nuclear cardiology procedures, clinical experience may be acquired in a period of time as short as 4 months. In institutions with a lower volume of procedures, a total of 6 months of clinical experience will be necessary for level 2 competency. This additional training should be dedicated to enhancing clinical skills and qualifying for Nuclear Regulatory Commission (NRC) licensure. The details of NRC licensure requirements are listed in the Appendix.

Didactic program. Appropriate radiation safety training (currently 200 h [see Appendix]) should be provided to satisfy NRC licensure requirements. The training should provide fellows with a series of lectures and laboratories dealing with basic radiation physics, radiation protection, radiopharmaceutical chemistry, radiation biology and instrumentation according to NRC requirements. This program might be scheduled

Table 1. Classification of Nuclear Cardiology Procedures

1. Standard nuclear cardiology procedures
   a. Myocardial (perfusion) imaging rest/exercise/pharmacologic (planar/SPECT)
   b. Gated equilibrium or "first-pass" radionuclide cineangiography (rest/exercise)
2. Less common nuclear cardiology procedures
   a. Myocardial infarction imaging
   b. Metabolic imaging (i.e., PET)
   c. Shunt studies

PET = positron emission tomography; SPECT = single-photon emission computed tomography.

Table 2. Summary of Training Requirements for Nuclear Cardiology

Level	Total Duration of Training	Total No. of Examinations
1	2 mo	(80 h interpretative experience)
2	4–6 mo (minimum of 200 h radiation safety)	300*
3	12 mo (minimum of 200 h radiation safety)	600*

*A minimum of 50 cases must be performed and interpreted under supervision. The remaining supervised interpretative experience can be obtained from a teaching file.

over a 12- to 24-month period concurrent with other fellowship assignments.

Clinical experience. The fellow should participate in interpretation of all nuclear cardiology imaging data for the 4- to 6-month training period. During the course of the 4- to 6-month training period, it is imperative that the fellow have experience in correlating catheterization/angiographic data with radionuclide-derived data in a minimum of 30 patients. A teaching conference in which the fellow presents the clinical material and scintigraphic results is an appropriate forum for such an experience. Another appropriate source of interpretative experience can consist of an established teaching file. For level 2 training, a total of 300 cases should be interpreted under supervision, either from direct patient studies or from the teaching file, consisting of diverse types of procedures (Table 1). Minutes or a written logbook should be kept; cases and diagnoses should also be listed to provide documentation.

Hands-on experience. Fellows acquiring level 2 training should have additional hands-on experience with patient studies. Additional intensive experience should be acquired in a minimum of 50 patients; optimally 25 patients for myocardial (perfusion) imaging and 25 patients for radionuclide angiography (total 50 patients). Such supervised experience should include pretest patient evaluation, radiopharmaceutical preparation (including experience with relevant radionuclide generators), performance of the study (rest, exercise dipyridamole or adenosine or other pharmacologic stress), administration of the dosage, calibration and setup of the gamma camera, setup of the imaging computer and processing the data for display after acquisition.

Additional experience. In addition, the training program must provide experience in computer methods for analysis of perfusion imaging studies, including single-photon emission computed tomography (SPECT), and ejection fraction and regional wall motion measurements from radionuclide angiographic studies.

Evaluation. Both the person responsible for the nuclear cardiology training program and the program director should also be responsible for evaluating the competence of the trainee in nuclear cardiology at the completion of the program. This can be accomplished by observing the performance of the fellow during the daily reading sessions or by a formal testing procedure, or both.

Advanced Training—Level 3 (Minimum of 1 Year)

For fellows who wish to pursue an academic career in nuclear cardiology or to direct a nuclear cardiology laboratory, an extended program is required. This can be part of the standard 3-year cardiology fellowship. In addition to the recommended program for level 2, this program should include active participation in ongoing laboratory or clinical research, or both, with individual responsibility for a segment of that research. In parallel with participation in a research program, the trainee should participate in clinical imaging activities for the total training period of ≥12 months, to include supervised interpretative experience in 600 cases. Hands-on experience should be similar to or greater than that required for the clinical practitioner (level 2). The fellow should be trained in most of the following areas:

- Qualitative interpretation of standard nuclear cardiology studies, including myocardial (perfusion) imaging, gated equilibrium studies, "first-pass" and infarct imaging studies
- Quantitative analysis of perfusion or metabolic studies
- Quantitative radionuclide angiographic analyses, including measurement of global and regional ventricular function
- SPECT studies
- PET studies (see later) when available.

The same method of evaluation of proficiency as indicated in level 2 should be applied.

The overall requirements for training in general nuclear cardiology are summarized in Table 2.

Specific Training in Cardiac Positron Emission Tomography

Cardiac PET is part of nuclear cardiology but is technically different and not widely available. Nevertheless, at this time, for institutions that have PET, training guidelines are appropriate. Training in this particular imaging technology should go hand-in-hand and may be concurrent with training in conventional nuclear cardiology but should include those aspects that are unique or specific to PET. Depending on the desired level of expertise, training in cardiac PET should include knowledge of substrate metabolism in the normal and diseased heart;

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knowledge of positron emitting tracers for blood flow, metabolism and neuronal activity, medical cyclotrons, radioisotope production and radiotracer synthesis; and principles of tracer kinetics and their in vivo application for the noninvasive measurements of regional metabolic and functional processes. The training should also include the physics of positron decay, aspects of imaging instrumentation specific to PET, production of radiopharmaceutical agents, quality control, handling of ultrashort-life radioisotopes, appropriate radiation protection and safety and regulatory aspects.

Consistent with the training guidelines for general nuclear cardiology, training should be divided into three classes.

General Training (2 Months)

This level is for cardiology fellows, in an institution where PET is available, who wish to become conversant with cardiac PET. Training should therefore be the same as for level 1 training in nuclear cardiology but should include aspects specific to cardiac PET. The additional proficiency to be acquired by physician trainees includes background in substrate metabolism, patient standardization and problems related to diabetes mellitus and lipid disorders, positron emitting tracers of flow and metabolism and technical aspects of PET imaging. A didactic program should include interpretation of cardiac PET studies of myocardial blood flow and substrate metabolism, diagnostic accuracy and cost-effectiveness of viability assessment and coronary artery disease detection and appreciation of radiation safety as specifically related to PET. Hands-on experience should include supervised observation and interpretation of cardiac PET studies.

Specialized Training (Total 4 to 6 Months)

This level of training is for fellows who wish to perform and interpret cardiac PET studies in addition to nuclear cardiology. This training should include all level 1 and 2 training in nuclear cardiology (4 to 6 months) as well as general training for cardiac PET. Specific aspects of training for PET should include radiation dosimetry, radiation protection and safety, dose calibration, handling of large doses of high energy radioactive material of short physical half-lives, quality assurance procedures and NRC safety and record keeping requirements. This level of training requires direct patient experience with a minimum of 40 patient studies of myocardial perfusion or metabolism, or both.

Advanced Training (Minimum 1 Year)

This level of training is intended for those cardiologists who wish to direct a cardiac PET laboratory or to pursue an academic career in cardiac PET. Similar to level 3 training in nuclear cardiology, this training should include active participation in laboratory and clinical research in parallel with clinical activities.

In addition to the requirements for general and specialized cardiac PET training (including standard nuclear cardiology training, as previously described), advanced training should include the following:

1. Basic principles of cyclotrons, isotope production, radiosynthesis, tracer kinetic principles and tracer kinetic models, cardiac innervation and receptors and methods for quantifying regional myocardial blood flow and substrate metabolism.
2. Image acquisition and processing (sinograms, errors in image reconstruction, correction routines for photon attenuation, patient misalignment).
3. Tissue kinetics of positron emitting tracers; in vivo application of tracer kinetic principles; tracer kinetic models, generation of tissue time activity curves and computer-assisted calculation of region of functional processes of the myocardium.
4. Computer-assisted data manipulation, quantitative image analysis and image display.

Appendix

The following are the current Nuclear Regulatory Commission (NRC) requirements for licensure to perform nuclear cardiologic studies, as quoted directly from the *Federal Register.* It is the intent of the American College of Cardiology training guides that fellows completing level 2 training should be eligible for NRC licensure according to the following NRC rules (1):*

Training for Imaging and Localization Studies

Except as provided in §35.970 or §35.971, the licensee shall require the authorized user of a radiopharmaceutical, generator or reagent kit in §35.200(a) to be a physician who

a. Is certified in
   1. nuclear medicine by the American Board of Nuclear Medicine;
   2. diagnostic radiology by the American Board of Radiology; or
   3. diagnostic radiology or radiology by the American Osteopathic Board of Radiology; or

b. has had classroom and laboratory training in basic radioisotope handling techniques applicable to the use of prepared radiopharmaceuticals, generators and reagent kits, supervised work experience and supervised clinical experience as follows:
   1. 200 h of classroom and laboratory training that includes
      i. radiation physics and instrumentation;
      ii. radiation protection;
      iii. mathematics pertaining to the use and measurement of radioactivity
      iv. radiopharmaceutical chemistry; and
      v. radiation biology; and
   2. 500 h of supervised work experience under the supervision of an authorized user that includes

*Some "agreement" states, by agreement with the NRC, have their own licensing requirements, which may differ from those of the NRC. For details, contact the American Society of Nuclear Cardiology.

i. ordering, receiving and unpacking radioactive materials safely and performing the related radiation surveys;
ii. calibrating dose calibrators and diagnostic instruments and performing checks for proper operation of survey meters;
iii. calculating and safely preparing patient dosages;
iv. using administrative controls to prevent the misadministration of by-product material;
v. using procedures to contain spilled by-product material safely and using proper decontamination procedures; and
vi. eluting technetium-99m from generator systems, measuring and testing the eluate for molybdenum-99 and alumina contamination and processing the eluate with reagent kits to prepare technetium-99m–labeled radiopharmaceuticals; and

3. 500 h of supervised clinical experience under the supervision of an authorized user that includes
i. examining patients and reviewing their case histories to determine their suitability for radioisotopic diagnosis, limitations or contraindications;
ii. selecting the suitable radiopharmaceuticals and calculating and measuring the dosages;
iii. administering dosages to patients and using syringe radiation shields;
iv. collaborating with the authorized user in the interpretation of radioisotope test results; and
v. patient follow-up; or

c. Has successfully completed a 6-month training program in nuclear medicine that has been approved by the Accreditation Council for Graduate Medical Education and that included classroom and laboratory training, work experience and supervised clinical experience in all the topics identified in paragraph b of this section.

Reference

1. U.S. Nuclear Regulatory Commission. Regulatory Guides (35.920)—Training for Imaging and Localization Studies. Federal Registrar. Washington, D.C.: Superintendent of Documents, U.S. Government Printing Office, Jan 1994.

Task Force 6: Training in Specialized Electrophysiology, Cardiac Pacing and Arrhythmia Management

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Clinical cardiac electrophysiology and cardiac pacing have matured significantly and are merging into a common cardiac subspecialty discipline. Today, complex cardiac arrhythmias are managed by cardiologists and cardiac surgeons with special expertise in cardiac electrophysiology, the use of implantable pacemakers and cardioverter-defibrillators and the application of other interventional techniques and treatments. Nonpharmacologic therapy also includes electrophysiologic mapping and subsequent catheter or surgical ablation as standard treatment for certain tachyarrhythmias. Many new antiarrhythmic agents with diverse mechanisms of action are often used therapeutically alone or in conjunction with implantable multiprogrammable arrhythmia control devices (pacemakers and implantable cardioverter-defibrillators).

In 1986, Task Force VI, Training in Cardiac Pacing, and Task Force VII, Training in Arrhythmias and Specialized Electrophysiologic Studies and Interventions, were published separately as a result of the Bethesda Conference 17 on adult cardiology training. The present task force combines these two closely related disciplines to reflect the current merging of science, art and practice of clinical cardiac electrophysiology.

General Standards and Environment

General Standards, Facilities and Faculty

Three organizations, the American College of Cardiology (ACC), American Heart Association (AHA) and The North American Society of Pacing and Electrophysiology (NASPE), have recently addressed training requirements and guidelines for pacemaker implantation (1), guidelines for use of implantable cardioverter-defibrillators in cardiovascular practice (2), training requirements for permanent pacemaker selection, implantation and follow-up (3) and teaching objectives for fellowship programs in clinical electrophysiology (4,5). The