

Evolution of Nuclear Medicine Training: Past, Present, and Future*

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Since the official inception of nuclear medicine in 1971, the practice of nuclear medicine and its training programs have undergone major revisions. Numerous procedures that were common in the 1970s are no longer available, and many new radiotracers and procedures have since been developed. Training programs have evolved from an unstructured experience before 1971 to 2 y of nuclear medicine training after 2 clinical years, to 2 y of nuclear medicine training after 1 clinical year and, most recently, to 3 y of nuclear medicine training after 1 clinical year. The most substantial content changes in the new 2007 training program requirements are an increased emphasis on 6 clinical competencies, an increased emphasis on Nuclear Regulatory Commission requirements, and a new CT training requirement that was spawned by the advent of PET/CT. In addition to the new training program requirements, residents will need to become familiar with the concept of maintenance of certification, which will continue to be an important component of their professional careers. Nuclear medicine is gradually evolving into molecular imaging. Hence, it is inevitable that in the near future, training programs will be required to place greater emphasis on molecular imaging in both clinical and research applications. The incorporation of molecular imaging will represent a significant paradigm shift for the specialty but will ensure that nuclear medicine will be a major part of medical practice for the foreseeable future.

Key Words: education; residency programs; ABNM; molecular imaging; history

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Nuclear medicine is one of the most dynamic fields in medicine. It is defined, in the new Accreditation Council for Graduate Medical Education (ACGME) program requirements, as “the clinical and laboratory medical specialty that uses radioactive and stable tracers to study physiologic, biochemical and cellular processes for diagnosis, therapy

and research.” Training in nuclear medicine has undergone major revisions since its official inception in 1971. This article is a summary of the major changes that have occurred, a review of the current training requirements, and a look toward the future as nuclear medicine evolves into molecular imaging.

Not surprisingly, in addition to major modifications in training, the practice of nuclear medicine has also markedly changed since 1971. The radiopharmaceuticals available then were fewer, and many of the common procedures performed at that time are no longer offered in the modern routine nuclear medicine clinic. The most common studies done in the early 1970s were brain scans with ^{99m}Tc-diethylenetriaminepentaacetic acid or glucoheptonate, liver scans with ^{99m}Tc-sulfur colloid, bone scans with ^{99m}Tc-pyrophosphate, renal scans with ¹³¹I-orthoiodohippurate, lung scans with ^{99m}Tc-macroaggregated albumin and ¹³³Xe, and thyroid imaging with ¹³¹I. At that time, nuclear medicine had already moved beyond the outdated studies of placenta localization with ¹³¹I-albumin, pancreas imaging with ⁷⁵Se-selenomethionine, liver imaging with ¹⁹⁸Au-gold colloid, and renal imaging with ²⁰³Hg-chlormerodrin.

In addition, nuclear medicine continues to evolve through the addition of new agents and procedures and the dwindling use of older, minimally used examinations. Some of the very useful and clinically important agents that have come and gone in the last decade are ^{81m}Kr for ventilation imaging, ¹²³I-iodoamphetamine for cerebral perfusion, ^{99m}Tc-albumin microspheres for lung perfusion, ^{99m}Tc-albumin microcolloid for liver imaging and sentinel node imaging, ^{99m}Tc-teboroxime for myocardial perfusion, and ¹²⁵I-fibrinogen for thrombosis. More recently, ¹¹¹In-antimyosin antibodies, ^{99m}Tc-apcitide for thrombus imaging, ^{99m}Tc-arcitumomab (CEAscan; Immunomedics Inc.), and ^{99m}Tc-fanolesomab (NeutroSpec; Palatin Technologies) were withdrawn from the market.

A significant aspect of nuclear medicine that has disappeared from the repertoire is radioimmunoassay (RIA). RIA was the major reason that pathologists represented one of the joint boards that participated in the founding of the American Board of Nuclear Medicine (ABNM). During the

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1970s and into the early 1980s, training programs were required to provide 2 mo of laboratory experience in RIA. However, beginning in the early 1980s, most hospitals insisted on centralizing assays in clinical laboratories overseen by pathologists, and because regulations regarding the possession and disposal of ^{125}I became more onerous, it became progressively more difficult to provide training in RIA for nuclear medicine residents. When fluorescent-antibody techniques, which did not require extensive record keeping, were developed, RIA essentially disappeared from modern medicine.

Major new procedures and materials that have been incorporated into nuclear medicine since the 1970s include myocardial perfusion imaging, gated blood-pool studies, hepatobiliary imaging, aerosol ventilation studies, labeled white blood cells, octreotide, metaiodobenzylguanidine, and parathyroid imaging. The fastest growing new modality is ^{18}F -FDG PET. With the recent addition of CT, creating coregistered anatomic and functional images, fusion studies have become an exciting and powerful new addition to the procedures that are performed.

Instrumentation has also changed dramatically since the early 1970s. Rectilinear scanners were commonly used for imaging when the ABNM was founded. The γ -camera, which was patented in 1958 and first marketed in 1961, was a relatively simple device. All imaging used analog techniques. Images appeared on cathode ray tubes and were recorded by photography. When Polaroid (Polaroid Corp.) instant photography became available, it was extensively used, often with a 3-lens system taking images at 3 different f-stops. Computers were first introduced in the mid-1970s and were predominantly used for renal and gated blood-pool imaging. These initial computers had 64 kilobytes of memory, no hard drives, and ~ 35.5 -cm (14-in.) removable storage disks with 2.4-megabyte capacities. Amazingly, this was the level of computer technology when SPECT was introduced in the early 1980s.

Before 1971, training programs were not regulated, and the duration and content of the programs varied. With the establishment of the ABNM as a conjoint board of radiologists, internal medicine physicians, and pathologists, training requirements began to be defined. The ABNM initially offered the opportunity to take an examination and become certified to a broad group of physicians who had interest and expertise in nuclear medicine. The initial board eligibility criteria were as follows: an internship and 10 y of experience in nuclear medicine; an internship, 1 y of an approved residency in internal medicine, pathology, or radiology, and 5 y of experience in nuclear medicine; certification by an American specialty board plus 1 y of training in nuclear medicine or 3 y of experience in nuclear medicine; or an internship plus 1 y of residency and 2 y of training in nuclear medicine. In the first 5 y, 2,800 physicians became board certified by the ABNM (Fig. 1).

Beginning in 1977, the requirements for board eligibility were considerably tightened, and the number of people

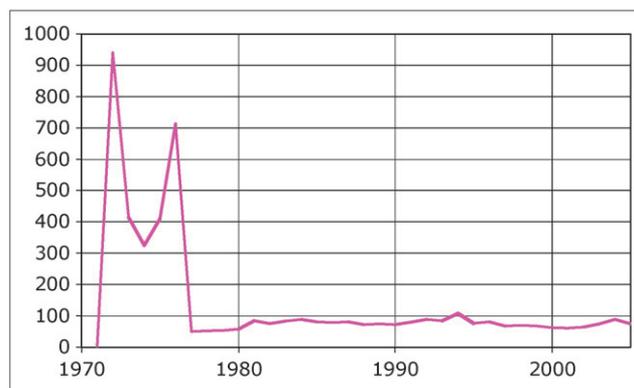


FIGURE 1. Number of ABNM certificates issued per year. Examination was offered for first time in 1972. Second peak, in 1975, occurred because in following year, entry requirements became considerably more stringent. During first 5 y, 2,800 physicians were board certified by ABNM. Since that time, through 2005, additional 2,145 physicians have been certified.

taking the certifying examination dropped to 80–100 per year, a level at which it has since remained. In 1977, the board eligibility requirements were 2 y of internal medicine, pathology, radiology, or other training “which is acceptable to 1 of the 3 sponsoring boards and the ABNM” followed by 2 y of training in an approved nuclear medicine program. In 1993, the requirement for 2 y of preparatory training was reduced to 1 y. The motivation for this change was apparently to try to increase the number of individuals entering the field. The fact that the number of physicians becoming ABNM certified did not increase in the subsequent years suggests that the change was not as effective as had been hoped.

Since nuclear medicine did not exist as an official specialty until 1971, before that time there was no mechanism to approve training programs. In the early 1970s, the mechanism for the approval of residency programs involved 2 committees of the American Medical Association: the Liaison Committee for Graduate Medical Education and the Nuclear Medicine Residency Review Committee (RRC). In 1981, the ACGME was formed and took over the tasks of accrediting nuclear medicine programs and defining training requirements. There had to be tight coordination between the ABNM and the RRC so that the training requirements would match the board eligibility requirements. This coordination was accomplished through the membership of the RRC. The RRC is composed of 2 representatives from each of 3 organizations: the ABNM, the Society of Nuclear Medicine, and the American Medical Association. Term duration for members is usually 6 y. The RRC meets twice per year to review, reaccredit, and accredit nuclear medicine programs and to determine whether the program requirements need revision. In the recent past, the program requirements have been revised every 4 or 5 y.

In the last revision, which became effective on January 2003, the major change was the addition of required

training in and evaluation of 6 clinical competencies. These competencies were agreed on through joint meetings between the ACGME and the American Board of Medical Specialties (ABMS) in the late 1990s. The first 4 medical specialty boards, the American Board of Ophthalmology, the American Board of Otolaryngology, the American Board of Obstetrics and Gynecology, and the American Board of Dermatology and Syphilology, agreed in 1934 to work together under a joint advisory board, that is, the ABMS. This organization has gradually evolved so that it currently includes 24 medical specialty boards, including the ABNM. The ABMS sets standards and is the overall governing organization for all of the medical specialty boards. There was broad agreement among all 24 medical specialty boards that there were common clinical competencies that should be expected of all physicians. Physicians from each specialty attended meetings and proposed the wording of the 6 clinical competencies for each specialty. The wording agreed on and incorporated into the nuclear medicine program requirements is as follows: "The residency program must require its residents to obtain competence in the six areas listed below to the level expected of a new practitioner. Programs must define the specific knowledge, skills, behaviors, and attitudes required, and provide educational experiences as needed in order for their residents to demonstrate the following:

"1. **Patient Care** that is compassionate, appropriate, and effective for the treatment of health [problems] and the promotion of health. Residents are expected to:

- "a. Obtain information about the patient related to the requested test or therapy using patient interview, chart and computer data base review, physical examination, and contact with the referring physician.
- b. Select appropriate procedures or therapy based on the referring physician's request and the patient's history. This step involves selection of the appropriate radiopharmaceutical, dose, imaging technique, data analysis, and image presentation. It also includes review of image quality, defining the need for additional images and correlation with other imaging studies such as x-rays, CT, MRI, or ultrasound.
- c. Communicate results promptly and clearly to the referring physician or other appropriate health care workers. This communication should include clear and succinct dictation of the results.
- d. Conduct therapeutic procedures. Therapeutic procedures must be done in consultation with an attending physician who is a licensed user of radioactive material. These procedures should include dose calculation, patient identity verification, explanation of informed consent, documentation of pregnancy status, counseling of patients and their families on radiation safety issues, and scheduling follow-up after therapy.

- e. Maintain records (logs) of participation in nuclear cardiology pharmacologic and exercise studies and in all types of therapy procedures.

"2. **Medical Knowledge** about established and evolving biomedical, clinical, and cognate sciences as well as the application of this knowledge to patient care. Residents should closely follow scientific progress in nuclear medicine and learn to incorporate it effectively for modifying and improving diagnostic and therapeutic procedures. Residents are expected to:

- "a. Become familiar with and regularly read the major journals in nuclear medicine. During the residency, this step will involve regular participation in journal club.
- b. Use computer technology including internet web sites and CDROM teaching disks.
- c. Participate in the annual in-service examination.
- d. Know and comply with radiation safety rules and regulations, including agreement NRC and/or state rules, local regulations, and the ALARA (as low as reasonably achievable) principles for personal radiation protection.
- e. Understand and use QC (quality control) procedures for imaging devices, laboratory instrumentation, and radiopharmaceuticals.

"3. **Practice-Based Learning and Improvement** that involves the investigation and evaluation of care for patients, the appraisal and assimilation of scientific evidence, and improvements in patient care. Residents must develop and continuously improve skills in obtaining medical knowledge by using new techniques as they develop in information technology. This includes:

- "a. Using the internet and computer data bases to search for patient information, disease, and technique information. Residents should also be familiar with viewing and manipulating images with the computer, both locally and remotely.
- b. Residents should improve their understanding of diseases and patient care by attending interspecialty conferences, correlative conferences, mortality and morbidity conferences, and utilization conferences.
- c. Patient follow-up is essential for determining the accuracy of study interpretation. Residents should regularly obtain such follow-up information and correlate the clinical findings with their study interpretation.

"4. **Interpersonal and Communication Skills** that result in the effective exchange of information and collaboration with patients, their families, and other health care professionals. Residents must communicate clearly and effectively and work well with each of the following groups:

- “a. Patients and their families.
 b. Physicians in nuclear medicine and radiology.
 c. Referring physicians from other specialties.
 d. Nuclear medicine technologists.
 e. Other health care workers throughout the institution.
- “5. **Professionalism**, as manifested through a commitment to carrying out professional responsibilities, adherence to ethical principles, and sensitivity to patients of diverse backgrounds. Residents are expected to always behave in a professional manner. This includes:
- “a. Consistent demonstration of completely ethical behavior.
 b. Respect for the dignity of patients and all members of the medical team.
 c. There should be no discrimination based on age, ethnicity, gender, disability, or sexual orientation.
 d. Residents should be responsive to patient’s needs by demonstrating integrity, honesty, compassion, and commitment.
 e. Residents should always respect the patient’s privacy and autonomy.
- “6. **Systems-Based Practice**, as manifested by actions that demonstrate an awareness of and responsiveness to the larger context and system of health care, as well as the ability to call effectively on other resources in the system to provide optimal health care. This involves learning to work in a variety of health care settings and understanding the inter-relationship with other health care professionals. Specifically, residents should be aware of:
- “a. Work conditions in hospitals, out-patient clinics, diagnostic centers, and private practice settings.
 b. Resource allocation and methods directed towards controlling health care costs such as Diagnostic Related Groups (DRGs), APC, and pre-certification by medical insurers.
 c. The concept of providing optimal patient care by selecting the most cost-effective procedures and using or recommending other diagnostic tests that might complement the nuclear medicine procedures. This also involves awareness of the relevant risk-benefit considerations.
 d. Basic financial and business skills to function effectively in current health care delivery systems. This includes an understanding and knowledge of coding, procedure charges, billing practices, and reimbursement mechanisms.”

These 6 clinical competencies have been and continue to be a source of concern and confusion for many program directors and residents. The initial approach from ACGME was to insert these competencies into the program requirements and let the programs begin to develop the means to teach and evaluate the competencies. Over the last 3 y, many different approaches have been developed and shared. During this time, the RRC has not been excessively critical of programs that have lagged behind in this area. However, beginning in 2007, ACGME expects programs to actually teach and evaluate all residents in these competencies. One tool that is widely used for this task is the 360° evaluation (Table 1).

The most recent revision of nuclear medicine program requirements, which will take effect in July 2007, will

TABLE 1
 Evaluation of Resident and Program*

Clinical competency	Evaluation
Patient care	Resident provides appropriate patient care and understands all pertinent regulations and safety issues.
Medical knowledge	Resident is building knowledge base in nuclear medicine and all associated basic sciences.
Interpersonal and communication skills	Resident dictates and communicates effectively with entire nuclear medicine team and referring physicians.
Professionalism	Resident is committed, ethical, and professionally responsible physician.
Practice-based learning and improvement	Resident understands how to evaluate problems in daily operation of nuclear medicine clinic, reflect on problems, formulate plan for change, implement it, and assess success of change.
Systems-based practice	Resident understands role of nuclear medicine in larger scheme (i.e., scheduling, billing, insurance, and institutional policies) and how to use studies in cost-effective ways.

*Six clinical competencies can provide underlying basis for 360° evaluation of resident and program. Concept is that evaluation of resident includes self-assessment as well as evaluation by faculty, peers (including residents in other specialties), technologists, secretaries, and patients. Because of practical issues, evaluation by all groups may not always be feasible. Resident should also be given opportunity to evaluate quality of program, particularly with regard to availability of training in required areas. Generally, evaluator provides assessment of performance relative to that expected for level of training on 5-point scale: 1 = definitely below; 2 = slightly below; 3 = about right; 4 = slightly above; 5 = definitely above.

require 3 y of training in nuclear medicine for residents who have had only 1 preparatory clinical year. The motivations behind this change included the expanded content of the field, especially PET and PET/CT, an opportunity for residents to become more clinically mature, and the goal of more closely matching the duration of nuclear medicine training with that seen in the rest of the world. There are 2 major exceptions to the requirement for 3 y of training. For residents who have already completed a clinical residency, such as internal medicine, and have become board eligible or board certified, the nuclear medicine training requirement is 2 y. For residents who have already completed a radiology residency and have become board eligible or board certified, the nuclear medicine training requirement is 1 y. The 2-y curriculum should provide general nuclear medicine content with less emphasis on endocrinologic, gastrointestinal, hematologic, and pulmonary studies. The 1-y curriculum should particularly emphasize PET, cardiac studies, and therapy.

The major changes in the program requirements are more explicit inclusion of NRC requirements for the training of authorized users and considerably more training in PET and CT. The NRC-related material was thought to be essential to ensure that nuclear medicine residents would be eligible to become authorized users for all aspects of nuclear medicine-related studies, including therapy. The inclusion of these requirements also ensures that ABNM certification will continue to be regarded as adequate evidence that ABNM diplomates are eligible to become authorized users.

The development and clinical use of PET and, subsequently, PET/CT have been the greatest changes in the field of nuclear medicine since the introduction of SPECT in the 1980s. It is clear that PET and PET/CT studies will be the most rapidly growing aspects of the field for some time. Virtually all nuclear medicine programs are now incorporating PET or PET/CT rotations into their programs. The relevant wording from the new requirements is as follows: "The program must provide adequate opportunity for residents to participate in and personally perform and analyze a broad range of common clinical nuclear medicine procedures. This opportunity must include experience in each of the following categories:

- "l) PET imaging of the heart, including studies of myocardial perfusion and myocardial viability.
- m) PET imaging of the brain, including studies of dementia, epilepsy, and brain tumors.
- n) PET imaging in oncology, including studies of tumors of the lung, head and neck, esophagus, colon, thyroid, and breast, as well as melanoma, lymphoma, and other tumors as the indications become established.
- o) Co-registration and image fusion of SPECT and PET images with computed tomography (CT) and magnetic resonance imaging (MRI) studies.
- p) Anatomic imaging of brain, head and neck, thorax, abdomen, and pelvis with CT to be able to understand

the correlation between anatomic and functional imaging. This training should include a minimum of 4 months of CT experience that may be combined with a rotation that includes PET-CT or SPECT-CT, although rotation on a CT service is desirable for part of the training. The experience must emphasize correlation of CT images associated with PET-CT or SPECT-CT. The resident must acquire sufficient experience with such studies under the supervision of qualified faculty to be able to supervise the performance and accurately correlate the CTs associated with PET-CT or SPECT-CT studies. This requirement does not apply to residents who have completed training in an ACGME-approved diagnostic radiology program."

Paragraph p resulted in the most discussion among program directors, the Nuclear Medicine RRC, and the Radiology RRC. The essence of this paragraph is that nuclear medicine residents will need to learn to identify the significant incidental findings in the CT portion of a PET/CT or SPECT/CT study. Many nuclear medicine programs are already providing this training, including dedicated CT rotations for their residents, however, all programs will be required to do so beginning July 2007.

The development of the 3-y program resulted from 3 y of discussion with program directors, members of the Nuclear Medicine RRC, and members of the ABNM. The first meeting of the Nuclear Medicine Program Directors Association (NMPDA) took place in Los Angeles, CA, in June 2002. The major item discussed was the proposed 3-y program. At the initial meeting, there was definitely a broad spectrum of opinion, but after 2 h of debate, the majority of attendees agreed that it was a good idea. Over the following 2 y, similar discussions took place at ABNM and RRC meetings and at subsequent NMPDA meetings. Eventually, a general consensus developed, solidifying an agreement to move forward and make the change. Once the new requirements were drafted and edited, they were presented to the ACGME, which sent them out for comments. There were significant comments from the Radiology RRC, necessitating modifications in the CT requirements. The most difficult part was Paragraph p, which required about 1 y of discussion before agreement was reached. The new program requirements were finally approved by the ACGME Program Requirements Committee on September 12, 2005, and will become effective on July 1, 2007.

The NRC language that has also been incorporated into the program requirements is as follows: "Specifically, instruction should include the chemistry of byproduct materials for medical use; ordering and unpacking radioactive materials safely and performing the related radiation surveys; calibrating instruments used to determine the activity of dosages and performing checks for proper operation of survey meters; calculating and safely preparing patient or human research subject dosages; using administrative controls to

prevent a medical event involving the use of unsealed byproduct material; using procedures to contain spilled byproduct material safely and using proper decontamination procedures; eluting generator systems appropriate for preparation of radioactive drugs for imaging and localization studies or that need a written directive; measuring and testing the eluate for radionuclide purity, and processing the eluate with reagent kits to prepare labeled radioactive drugs; and administering dosages of radioactive drugs for uptake, dilution, excretion, and imaging and localization studies.”

It is clear that residency programs must include hands-on experience for residents in a radiopharmacy laboratory as part of their training. Many programs have provided this experience in the past, but it is clear that all must do so in the future. This same requirement applies to all radiology residents who wish to become authorized users.

The shift to the 3-y program is an opportunity to reorganize training program curricula. Because of the increasing emphasis on the 6 clinical competencies, the following is a proposed residency program format that is organized in terms of the clinical competencies. Such an approach will result in a comprehensive inclusion of the competencies with the training objectives as opposed to individually addressing these items, a clearly more difficult task. As a guideline to nuclear medicine program directors, the suggested general organization for the educational content for each year of the program is presented. A summary of this suggested organization for all years is shown in Table 2.

THREE-YEAR PROGRAM (PRECEDED BY 1 CLINICAL YEAR, TYPICALLY IN POSTGRADUATE YEAR 1 ACGME-APPROVED PROGRAM): FIRST YEAR

Patient Care

1. Become familiar with the operations of a nuclear medicine clinic, including evaluation of the clinical request, planning and monitoring of the procedure, interpretation of the study, and dictation of the final report after faculty review.
2. Learn basic radiation safety.
3. Learn how to interview thyroid therapy patients, calculate therapeutic radioiodine doses, and obtain informed consent.
4. Begin to participate in the stress portion of myocardial perfusion studies.
5. Begin patient procedure logs to document participation in nuclear cardiology, thyroid therapy, antibody therapy, bone therapy (^{89}Sr and ^{153}Sm), and PET and CT studies.

Medical Knowledge

1. Learn basic physics of nuclear medicine.
2. Learn basic radiopharmacy and quality control (preferred: dedicated radiopharmacy rotation).
3. Learn basic nuclear medicine instrumentation and quality control (preferred: hands-on experience).

4. Learn appropriate radiopharmaceuticals, procedures, and basic interpretations for the most common nuclear medicine studies (bone scans, thyroid studies, lung scans, cardiac studies, hepatobiliary scans, renal scans, gastric emptying studies, and ^{18}F -FDG studies).
5. Begin critical review of the major nuclear medicine literature (journal club participation).
6. Begin annual participation in the ABNM in-service examination.

Interpersonal and Communication Skills

1. Use digital dictation/voice recognition systems as appropriate for the institution.
2. Learn the appropriate format for a nuclear medicine report.
3. Begin to formulate a concise, meaningful, and accurate nuclear medicine report.
4. Learn to use Word (Microsoft Corp.) and Power Point (Microsoft Corp.) for presentations.
5. Understand the need and style for oral communication of results to referring physicians.
6. Begin participation in clinical settings (intra- and interdepartmental conferences).

Professionalism

1. Begin to understand how to be a committed, ethical, and professionally responsible nuclear medicine physician who is sensitive to a diverse socioeconomic health care system (patient and health care team).
2. Understand patient privacy issues.
3. Pursue membership and involvement in organized nuclear medicine societies.

Practice-Based Learning and Improvement

1. Use computer technology and the Internet as tools for the acquisition of evidence-based medical knowledge from existing published and online educational resources.
2. Begin patient follow-up as related to nuclear medicine procedures, including radiopharmaceutical therapy.

Systems-Based Practice

1. Learn to use nuclear medicine computer systems, radiology information systems, and picture archiving and communications systems (PACS) workstations.
2. Begin a scholarly research project to present at a state, regional, or national meeting or for publication in a peer-reviewed journal.
3. Present 1 didactic departmental nuclear medicine lecture.
4. Understand basic billing and coding issues in nuclear medicine.

TABLE 2
Summary of Clinical Competencies That Need to Be Learned in 3-y, 2-y, and 1-y Programs

Clinical competency	Task	Program					
		3 y			2 y		1 y
		Year 1	Year 2	Year 3	Year 1	Year 2	
Patient care	1. Become familiar with NM clinic	✓			✓		✓
	2. Assume responsibility in NM clinic		✓	✓		✓	✓
	3. Understand NRC regulations		✓	✓		✓	✓
	4. Understand how to perform NM radiotherapy		✓	✓		✓	✓
	5. Learn basic radiation safety	✓			✓		✓
	6. Learn how to interview patients	✓			✓		✓
	7. Supervise myocardial perfusion studies	✓	✓	✓	✓	✓	✓
	8. Maintain procedure logs	✓	✓	✓	✓	✓	✓
Medical knowledge	1. Learn basic physics	✓	✓		✓		✓
	2. Learn basic radiopharmacy	✓	✓		✓		✓
	3. Learn PET radiopharmacy		✓			✓	✓
	4. Learn basic NM instrumentation	✓			✓		✓
	5. Learn to interpret studies	✓			✓		✓
	6. Learn to interpret PET/CT and SPECT/CT		✓			✓	✓
	7. Attend CT and MRI conferences		✓	✓		✓	✓
	8. Participate in journal clubs	✓	✓	✓	✓	✓	✓
	9. Take ABNM in-service examination	✓	✓	✓	✓	✓	✓
Interpersonal and communication skills	1. Learn to dictate	✓			✓		
	2. Learn to use Word and Power Point	✓			✓		
	3. Understand need for accurate communication	✓			✓		✓
	4. Participate in NM consultations		✓	✓		✓	✓
	5. Participate in intra- and interdepartmental conferences	✓	✓	✓	✓	✓	✓
Professionalism	1. Understand how to be committed, ethical, and professionally responsible physician	✓	✓	✓	✓	✓	✓
	2. Understand patient privacy issues	✓	✓	✓	✓	✓	✓
	3. Submit NRC forms to become authorized user			✓		✓	✓
	4. Apply for ABNM certification examination			✓		✓	✓
	5. Pursue membership and involvement in NM societies	✓	✓	✓	✓	✓	✓
Practice-based learning and improvement	1. Use computer technology and Internet	✓	✓	✓	✓	✓	✓
	2. Review patient follow-up	✓	✓	✓	✓	✓	✓
	3. Begin quality assurance project: identify problem, reflect on it, form plan, execute it, and assess result		✓	✓	✓	✓	✓
	4. Participate in NM peer review process		✓	✓		✓	✓
	5. Participate in graduate medical education internal RRC		✓	✓		✓	
	6. Become familiar with practice performance guidelines		✓	✓	✓	✓	✓
	7. Become familiar with ABNM MOC process			✓		✓	✓
Systems-based practice	1. Learn to use all relevant computer systems	✓			✓		✓
	2. Begin research project	✓	✓		✓	✓	✓
	3. Present research project at regional or national meeting		✓	✓		✓	✓
	4. Present didactic departmental NM lectures	✓	✓	✓		✓	✓
	5. Understand basic billing and coding	✓	✓	✓		✓	✓
	6. Understand cost-effectiveness		✓	✓		✓	✓

NM = nuclear medicine.

THREE-YEAR PROGRAM: SECOND YEAR

Patient Care

1. Begin to assume clinical responsibility for and supervision of the operations of a nuclear medicine clinic, including quality control issues.
2. Understand NRC regulations as applied to nuclear medicine and patient safety (preferred: dedicated experience with the Radiation Safety Office or its equivalent).
3. Assume increasing responsibility and understanding in the therapeutic uses of unsealed radiopharmaceuticals, including the following: radioiodine; painful bone disease; radiolabeled antibodies; malignant effusions; and therapy of hematologic, endocrine, and metabolic disorders.
4. Continue to maintain patient procedure logs.

Medical Knowledge

1. Increase depth of understanding of basic sciences, including physical science, instrumentation, radiobiology and radiation protection, mathematics and statistics, and radiopharmaceutical chemistry.
2. Learn the guidelines for conducting and interpreting more complex studies, including the following: the spectrum of musculoskeletal, cardiac, endocrinologic, gastrointestinal, hematologic, oncologic, neurologic, pulmonary, and genitourinary studies; non-¹⁸F-FDG PET agents; receptor and peptide imaging studies; and non-imaging studies.
3. Participate in radiology conferences in the basic principles of CT, ultrasound, and MRI.
4. Learn to understand and interpret coregistration and fusion studies, including learning to interpret CT studies (preferred: dedicated rotations in radiology).
5. Understand a PET radiopharmacy (preferred: dedicated rotation).
6. Learn to process for display and review basic nuclear medicine studies, such as myocardial perfusion, radionuclide ventriculography, gastric emptying, and thyroid uptake.
7. Routinely present at and participate in journal clubs.

Interpersonal and Communication Skills

1. Interpret and generate a preliminary dictation of nuclear medicine studies before faculty review.
2. Actively participate in nuclear medicine consultation with clinicians.
3. Present at intra- and interdepartmental conferences.

Professionalism

1. Be a committed, ethical, and professionally responsible nuclear medicine physician who is sensitive to a diverse socioeconomic health care system (patient and health care team).
2. Adhere to patient privacy issues.

3. Maintain membership and involvement in organized nuclear medicine societies.

Practice-Based Learning and Improvement

1. Begin to perform self-reflection in identifying patient care and practice deficiencies, be able to formulate an intervention and deficiency reassessment.
2. Participate in the nuclear medicine peer review process.
3. Become familiar with recommended practice performance guidelines as approved by the Society of Nuclear Medicine and the American College of Radiology.
4. Routinely follow up radionuclide therapy patients.
5. Begin a quality assurance project.

Systems-Based Practice

1. Participate in an institutional graduate medical education internal RRC.
2. Prepare a scholarly research project for presentation or publication.
3. Present 2 didactic nuclear medicine departmental lectures.
4. Begin to understand resource allocation as related to cost-effectiveness in nuclear medicine.

THREE-YEAR PROGRAM: THIRD YEAR

Patient Care

1. Deliver diagnostic and therapeutic nuclear medicine procedures that are compassionate, appropriate, effective, and cost conscious and that contribute to patient care over a diverse socioeconomic population.
2. Become sufficiently competent to independently be responsible for the supervision and operations of a nuclear medicine clinic as related to triage procedures, health care provider consultations, and supervision and interpretation of diagnostic studies. The supervising faculty, however, should be readily available for consultations.
3. Become sufficiently competent to independently and appropriately evaluate patients for therapy with radioiodine and radiolabeled antibodies and for the management of painful bone disease.
4. Complete required patient procedure logs.

Medical Knowledge

1. Acquire established and evolving biomedical, clinical, and cognitive evidence-based medical knowledge in the specialty of nuclear medicine.
2. Routinely critically review the major nuclear medicine and related literature with continued participation in journal clubs.

Interpersonal and Communication Skills

1. Interpret and generate a preliminary dictation of nuclear medicine studies for faculty review.

2. Become a primary nuclear medicine consultant for the health care team. The supervising faculty, however, should be readily available for consultations.
3. Routinely use effective verbal and nonverbal communication skills as they apply to patient care.
4. Become a primary presenter and lead case discussions in intra- and interdepartmental conferences regarding nuclear medicine procedures and topics.
6. Begin patient procedure logs to document participation in nuclear cardiology, thyroid therapy, antibody therapy, bone therapy (^{89}Sr and ^{153}Sm), and PET and CT studies.

Professionalism

1. Be a committed, ethical, and professionally responsible nuclear medicine physician who is sensitive to a diverse socioeconomic health care system (patient and health care team).
2. Submit the appropriate NRC forms to apply for authorized user status.
3. Apply for the certifying ABNM examination.
4. Maintain membership and involvement in organized nuclear medicine societies.

Practice-Based Learning and Improvement

1. Develop active critical reflection and improvement as applied to patient care.
2. Complete and submit a quality assurance project.
3. Become familiar with the ABNM Maintenance of Certification (MOC) process for implementation after completion of the nuclear medicine residency.

Systems-Based Practice

1. Submit a scholarly research project for presentation or publication.
2. Present 2 didactic nuclear medicine departmental lectures.
3. Understand the complexity of the health care system and develop the ability to use health care resources for optimal and cost-effective patient care in nuclear medicine procedures.

TWO-YEAR PROGRAM (PRECEDED BY RESIDENCY IN CLINICAL SPECIALTY): FIRST YEAR

Patient Care

1. Become familiar with the operations of a nuclear medicine clinic, including evaluation of the clinical request, planning and monitoring of the procedure, interpretation of the study, and dictation of the final report after faculty review.
2. Begin to assume clinical responsibility of and supervision of the operations of a nuclear medicine clinic, including quality control issues.
3. Learn basic radiation safety.
4. Learn how to interview thyroid therapy patients, calculate therapeutic radioiodine doses, and obtain informed consent.
5. Begin participation in the stress portion of myocardial perfusion studies.

Medical Knowledge

1. Learn basic physics of nuclear medicine, including physical science, instrumentation, radiobiology and radiation protection, mathematics and statistics, and radiopharmaceutical chemistry.
2. Learn basic radiopharmacy and quality control (preferred: dedicated radiopharmacy rotation).
3. Learn basic nuclear medicine instrumentation and quality control (preferred: hands-on experience).
4. Learn appropriate radiopharmaceuticals, procedures, and basic interpretations for the most common nuclear medicine studies (bone scans, thyroid studies, lung scans, cardiac studies, hepatobiliary scans, renal scans, gastric emptying studies, and ^{18}F -FDG studies).
5. Learn the guidelines for conducting and interpreting more complex studies, including the following: the spectrum of musculoskeletal, cardiac, endocrinologic, gastrointestinal, hematologic, oncologic, neurologic, pulmonary, and genitourinary studies; non- ^{18}F -FDG PET agents; receptor and peptide imaging studies; and nonimaging studies.
6. Participate in radiology conferences in the basic principles of CT, ultrasound, and MRI.
7. Begin critical review of the major nuclear medicine literature (journal club participation).
8. Begin annual participation in the ABNM in-service examination.

Interpersonal and Communication Skills

1. Use digital dictation/voice recognition systems as appropriate for the institution.
2. Learn the appropriate format for a nuclear medicine report.
3. Begin to formulate a concise, meaningful, and accurate nuclear medicine report.
4. Learn to use Word and Power Point for presentations.
5. Understand the need and style for oral communication of results to referring physicians.
6. Begin participation in clinical settings (intra- and interdepartmental conferences).

Professionalism

1. Begin to understand how to be a committed, ethical, and professionally responsible nuclear medicine physician who is sensitive to a diverse socioeconomic health care system (patient and health care team).
2. Understand patient privacy issues.
3. Pursue membership and involvement in organized nuclear medicine societies.

Practice-Based Learning and Improvement

1. Use computer technology and the Internet as tools for the acquisition of evidence-based medical knowledge from existing published and online educational resources.
2. Begin patient follow-up as related to nuclear medicine procedures, including radiopharmaceutical therapy.
3. Become familiar with recommended practice performance guidelines as approved by the Society of Nuclear Medicine and the American College of Radiology.
4. Late in the year, begin a quality assurance project.

Systems-Based Practice

1. Learn to use nuclear medicine computer systems, radiology information systems, and PACS workstations.
2. Begin a scholarly research project to present at a state, regional, or national meeting or for publication in a peer-reviewed journal.
3. Present 1 didactic departmental nuclear medicine lecture.
4. Understand basic billing and coding issues in nuclear medicine.

TWO-YEAR PROGRAM: SECOND YEAR

Patient Care

1. Become sufficiently competent to independently be responsible for the supervision and operations of a nuclear medicine clinic as related to triage procedures, health care provider consultations, and supervision and interpretation of diagnostic studies. The supervising faculty, however, should be readily available for consultations.
2. Deliver diagnostic and therapeutic nuclear medicine procedures that are compassionate, appropriate, effective, and cost conscious and that contribute to patient care over a diverse socioeconomic population.
3. Become sufficiently competent to independently and appropriately evaluate patients for therapy with radioiodine and radiolabeled antibodies and for the management of painful bone disease.
4. Understand NRC regulations as applied to nuclear medicine and patient safety (preferred: dedicated experience with the Radiation Safety Office or its equivalent).
5. Complete required patient procedure logs.

Medical Knowledge

1. Understand a PET radiopharmacy (preferred: dedicated rotation).
2. Learn to process for display and review basic nuclear medicine studies, such as myocardial perfusion, radio-nuclide ventriculography, gastric emptying, and thyroid uptake.

3. Acquire established and evolving biomedical, clinical, and cognitive evidence-based medical knowledge in the specialty of nuclear medicine.
4. Routinely critically review the major nuclear medicine and related literature with continued participation in journal clubs.

Interpersonal and Communication Skills

1. Interpret and generate a preliminary dictation of nuclear medicine studies for faculty review.
2. Become a primary nuclear medicine consultant for the health care team. The supervising faculty, however, should be readily available for consultations.
3. Routinely use effective verbal and nonverbal communication skills as they apply to patient care.
4. Become a primary presenter and lead case discussions in intra- and interdepartmental conferences regarding nuclear medicine procedures and topics.

Professionalism

1. Be a committed, ethical, and professionally responsible nuclear medicine physician who is sensitive to a diverse socioeconomic health care system (patient and health care team).
2. Submit the appropriate NRC forms to apply for authorized user status.
3. Apply for the certifying ABNM examination.
4. Maintain membership and involvement in organized nuclear medicine societies.

Practice-Based Learning and Improvement

1. Develop active critical reflection and improvement as applied to patient care.
2. Complete and submit a quality assurance project.
3. Become familiar with the ABNM MOC process for implementation after completion of the nuclear medicine residency.

Systems-Based Practice

1. Participate in an institutional graduate medical education internal RRC.
2. Submit a scholarly research project for presentation or publication.
3. Present 2 didactic nuclear medicine departmental lectures.
4. Understand the complexity of the health care system and develop the ability to use health care resources for optimal and cost-effective patient care in nuclear medicine procedures.

ONE-YEAR PROGRAM (PRECEDED BY RESIDENCY IN RADIOLOGY)

Patient Care

1. Become familiar with the operations of a nuclear medicine clinic, including evaluation of the clinical request, planning and monitoring of the procedure, interpretation

of the study, and dictation of the final report after faculty review.

2. Begin to assume clinical responsibility for and supervision of the operations of a nuclear medicine clinic, including procedures and quality control issues. During the year, become sufficiently competent to independently be responsible for the supervision and operations of the nuclear medicine clinic. The supervising faculty, however, should be readily available for consultations.
3. Learn basic radiation safety.
4. Understand NRC regulations as applied to nuclear medicine and patient safety.
5. Learn how to interview thyroid therapy patients, calculate therapeutic radioiodine doses, and obtain informed consent.
6. Begin to participate in the stress portion of myocardial perfusion studies.
7. Begin patient procedure logs to document participation in nuclear cardiology, thyroid therapy, antibody therapy, bone therapy (^{89}Sr and ^{153}Sm), and PET and CT studies.

Medical Knowledge

1. Learn basic physics of nuclear medicine, including physical science, instrumentation, radiobiology and radiation protection, mathematics and statistics, and radiopharmaceutical chemistry.
2. Learn basic radiopharmacy, PET radiopharmacy, and quality control (preferred: dedicated radiopharmacy rotation).
3. Learn basic nuclear medicine instrumentation and quality control (preferred: hands-on experience).
4. Learn to process for display and review basic nuclear medicine studies.
5. Learn appropriate radiopharmaceuticals, procedures, and basic interpretations for the most common nuclear medicine studies (bone scans, thyroid studies, lung scans, cardiac studies, hepatobiliary scans, renal scans, gastric emptying studies, and ^{18}F -FDG studies).
6. Learn the guidelines for conducting and interpreting more complex studies, including the following: spectrum of musculoskeletal, cardiac, endocrinologic, gastrointestinal, hematologic, oncologic, neurologic, pulmonary, and genitourinary studies; non- ^{18}F -FDG PET agents; receptor and peptide imaging studies; and nonimaging studies.
7. Begin critical review of the major nuclear medicine literature (journal club participation).
8. Begin annual participation in the ABNM in-service examination.

Interpersonal and Communication Skills

1. Interpret and generate a preliminary dictation of nuclear medicine studies for faculty review.
2. Become a primary nuclear medicine consultant for the health care team. The supervising faculty, however, should be readily available for consultations.

3. Routinely use effective verbal and nonverbal communication skills as they apply to patient care.
4. Become a primary presenter and lead case discussions in intra- and interdepartmental conferences regarding nuclear medicine procedures and topics.

Professionalism

1. Be a committed, ethical, and professionally responsible nuclear medicine physician who is sensitive to a diverse socioeconomic health care system (patient and health care team).
2. Submit the appropriate NRC forms to apply for authorized user status.
3. Apply for the certifying ABNM examination.
4. Pursue membership and involvement in organized nuclear medicine societies.

Practice-Based Learning and Improvement

1. Develop active critical self-reflection and improvement as applied to patient care.
2. Begin patient follow-up as related to nuclear medicine procedures, including radiopharmaceutical therapy.
3. Become familiar with recommended practice performance guidelines as approved by the Society of Nuclear Medicine and the American College of Radiology.
4. Become familiar with the ABNM MOC process for implementation after completion of the nuclear medicine residency.
5. Complete and submit a quality assurance project.

Systems-Based Practice

1. Learn to use nuclear medicine computer systems.
2. Submit a scholarly research project to present at a state, regional, or national meeting or for publication in a peer-reviewed journal.
3. Present 1 didactic departmental nuclear medicine lecture.
4. Understand basic billing and coding issues in nuclear medicine.
5. Understand the complexity of the health care system and develop the ability to use health care resources for optimal and cost-effective patient care in nuclear medicine procedures.

Although MOC is not technically part of the training of nuclear medicine residents, it is so intimately connected that it has to be part of their understanding of their responsibilities once they complete training. MOC is a concept that was developed within the ABMS as a way to ensure that practicing, board-certified physicians maintain competency. For ABNM diplomates to maintain certification, there are 4 requirements: an unrestricted medical license, participation in lifelong learning and in periodic self-assessment, recertification examinations at 10-y intervals, and evidence of evaluation of performance in practice. The interaction with residency training programs involves the last 3 requirements. The third requirement is very obvious.

A major goal of training nuclear medicine residents must be to prepare them to be able to pass the certifying examination. The second requirement underscores the necessity to keep up with the field. The changes in nuclear medicine in recent years have been substantial, and an active practitioner must understand that learning does not end at the conclusion of residency training. The tools available to a practicing nuclear medicine physician are also available to residents and should be used during training programs. These include books, journals, Web-based programs, CD-based programs, and workshops as well as regional and national meetings. It is essential that residents be exposed to these resources during training programs to ensure that they will continue to use them once they have graduated and are in practice. The fourth requirement is an extension of the 6 clinical competencies into the postresidency career. This is the aspect of MOC that the boards have had the most difficulty defining, and the conditions for fulfilling the fourth requirement have not been completely established. It is important that during training, residents understand the 6 clinical competencies, so that they will be able to apply them in their subsequent practice and thus will be able to understand and participate in MOC programs, once they are firmly defined. MOC is here to stay. Its implications for the way in which nuclear medicine physicians and residents will practice in the future cannot be ignored. Thus, it is essential that extensive discussions about the details of MOC be included throughout the years of training.

CONCLUSION

In the future, it is clear that the next major change in nuclear medicine training will be the inclusion of molecular imaging. Although much of nuclear medicine is certainly

molecular imaging, the new areas of practice and training will include metabolism, receptor-targeted agents, reporter genes, apoptosis, hypoxia, and probably other areas not yet envisioned. Optical imaging, including fluorescence agents and emitters such as luciferase, will also probably be an important component. A significant problem that will be encountered is that the nuclear medicine academic faculty will need to understand what molecular imaging is to be able to teach the fundamental principles to residents. Therefore, active participation in continuing education programs and self-assessment modules, as they become available, will be required. Another problem is that many of the agents and procedures that are defined as being part of molecular imaging are not approved for clinical studies. It is critical that this problem not be used as an excuse to delay entry into the field. Waiting for studies to become clinical reality means that someone else has done the work and will expect to do the studies. Currently, much of the research in molecular imaging is being done in animal imaging facilities and in phase I and phase II clinical trials. If nuclear medicine is to play a major role in molecular imaging, then faculty and residents must actively participate in these research efforts. This goal represents a major paradigm shift for the specialty but will ensure that nuclear medicine will be a major part of medical practice for the foreseeable future.

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