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A Perspective of the future of nuclear medicine training and certification

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Abstract

Nuclear Medicine has evolved from a medical subspecialty using quite basic tests to one using elaborate methods to image organ physiology and has truly become “Molecular Imaging”. Concurrently, there has also been a timely debate about who has to be responsible for keeping pace with all of the components of the developmental cycle; imaging, radiopharmaceuticals and instrumentation. Since the foundation of the ABNM, the practice of Nuclear Medicine and the process toward certification have undergone major revisions. At present, the debate is focused on the inevitable future convergence of Radiology and Nuclear Medicine. The potential for further cooperation or fusion of the American Board of Radiology (ABR) and the American Board of Nuclear Medicine (ABNM) is likely to bring about a new path for Nuclear Medicine and Molecular Imaging training. If the merger is done carefully, respecting the strengths of both partners equally, there is an excellent potential to create a hybrid Nuclear Medicine – Radiology specialty that combines Physiology and Molecular Biology with detailed anatomic imaging that will sustain the innovation that has been central to nuclear medicine residency and practice. Herein, we also introduce a few basic trends in imaging utilization in the United States. These trends do not predict future utilization, but highlight the need for an appropriately credentialed practitioner to interpret these examinations and provide value to the healthcare system.

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Introduction

In the several decades in which Nuclear Medicine has coalesced as a medical subspecialty, the routine use of radionuclides has resulted in a multitude of effective diagnostic and therapeutic tests. It has developed from quite simple *in vitro* tests to elaborate methods to image organ function. As we have developed the means to measure biologic processes on a subcellular level, radionuclide technologies have paralleled these advances and have been more precisely termed “Molecular Imaging”. As the imaging and therapy techniques have advanced, there has also been a parallel debate about who is the best steward of Molecular Imaging future. This is a debate that has questioned who has the aptitude and bandwidth to keep pace with all of the components of the developmental cycle -- imaging, radiopharmaceuticals and instrumentation.

The establishment of the American Board of Nuclear Medicine in 1971 (co-sponsored by the American Boards of Internal Medicine, Pathology, and Radiology) was done to homogenize the Nuclear Medicine residency programs and provide a roadmap for certification.(1) Since then, the practice of Nuclear Medicine and the process toward certification have undergone major revisions as new radiotracers have been approved for human use, and outdated procedures have been replaced. In recent years, as Nuclear Medicine has evolved into molecular imaging, a greater emphasis has been placed on synergistic clinical and research applications. This has firmly established the practice as a strong adjunct to everyday medical practice as well as Precision Medicine. (2)

At present, the debate is focused on the inevitable future convergence of Radiology and Nuclear Medicine -- merging the capabilities of anatomical and functional imaging into the new discipline of Molecular Imaging. The emphasis (as will be detailed later in this article) is on establishing residency training programs that will provide additional instruction in Physiology and Molecular Biology in order to overcome the weaknesses in current Nuclear Medicine and Radiology training programs while synergizing their strengths. In this article we take a look at the past, the present and the plausible common future of training in Nuclear Medicine and Radiology. A short statement of utilization of a subset of these techniques follows mostly to highlight the trends that the appropriately trained practitioner will need to follow. A wide variety of hybrid imaging techniques where the radiopharmaceutical, instrument and indication will need require a skilled interpreting physician to extract value from an intrinsically valuable commodity.

Evolution of U.S. Nuclear Medicine Training Programs

The Brookhaven National Laboratory Division of Medicine and Biology, in the mid 1960's presented 3 programs to the academic community and the Boards of Internal Medicine, Pathology and Radiology, who represented the major users of radioisotopes, regarding the clinical importance of diagnostic and therapeutic uses of available radionuclides. Although initially Pathology and Radiology delegates demonstrated interest to create specialty certification in Nuclear Medicine, they could not agree as to how to set up the certification requirements and examination. (1, 3, 4) (Figure 1)

ABNM

In the late 1960's, the American Board of Radiology (ABR) offered the Society of Nuclear Medicine (SNM) support to create a certifying examination in Nuclear Medicine. Drs John and Ernest Lawrence persuaded the ABR, along with the American Boards of Internal Medicine (ABIM), and Pathology (ABP), to work together to form a conjoint Board partially supported by the SNM. Finally, on July 28, 1971 the ABNM was incorporated to the American Board of Medical Specialties (ABMS). (1) Initially there were a number of administrative issues that had to be addressed. For example, all candidates for certification had to be approved by at least one of the 3 sponsoring boards, and all activities of the conjoint ABNM had to be permitted by all 3 sponsors. Finally, on May 31, 1972, following much debate and controversy, the ABR and ABP were allowed by the ABMS, to issue subspecialty certifications in Nuclear Radiology and Radioisotopic Pathology respectively, in cooperation with the conjoint Board.(1, 3, 4) Dr. Joseph Ross, who was the first Executive Director of the ABNM, was actively involved in overcoming many of these obstacles to finally create the ABNM, although it was not until 1985 that the ABNM was granted primary Board status as an independent organization, and took its place as 1 of the 24 member Boards of the ABMS.(1)

The establishment of the ABNM allowed harmonizing the training requirements and duration of the programs. Physicians who had interest and expertise in Nuclear Medicine were then given the opportunity to take an examination and become certified. However, because Nuclear Medicine was not an official specialty until 1971, there was no organization in charge of the regulation of training programs.

ACGME and program regulations

In the early 1970s, 2 committees were responsible for the approval of residency programs: the Liaison Committee for Graduate Medical Education and the Nuclear Medicine Residency Review Committee (RRC). (2) Later, in 1981, the Accreditation Council on Graduate Medical Education (ACGME) was founded. The ACGME provided oversight/coordination of the various Residency Review Committees (RRCs) including Nuclear Medicine. In this capacity they had the obligation and authority to accredit Nuclear Medicine programs and define the training requirements. All residency programs are reviewed by an RRC to establish that the program content, institutional support facilities, faculty, and curriculum meet the educational requirements in order to make the resident eligible to take the specialty Board examination. (1) Board eligibility criteria initially consisted of a clinical year and 10 years of experience in Nuclear Medicine; an internship, 1 year of an accepted residency in internal Medicine, pathology, or Radiology, and 5 years of experience in Nuclear Medicine; certification by an American specialty board plus 1 year of training in Nuclear Medicine or 3 years of experience in Nuclear Medicine; or an internship plus 1 year of residency followed by 2 years of training in Nuclear Medicine. Board certification by the ABNM was obtained by 2800 physicians in the first 5 years.(2) With new regulations for board eligibility in 1977 the number of certificates issued by year dropped to 80–100, a level that has remained stable until today. It still required 2 years of training in an official Nuclear Medicine program in addition to 2 years of internal Medicine,

Pathology, Radiology, or other training “which is acceptable to 1 of the 3 sponsoring boards and the ABNM”. The preparatory training was reduced from 2 to 1 years in 1993 with the goal of increasing the number of physicians joining the specialty although this objective was not achieved and the number of physicians taking the board examination has remained stable.(2) (Figure 2)

ACGME and Competency-based training

In the January 2003, Nuclear Medicine incorporated the required training in and evaluation of 6 clinical competencies that were first agreed on between the ACGME and the American Board of Medical Specialties (ABMS) in the late 1990s. The ABMS is the other major organization that provides oversight of medical training, by providing testing and certification of physicians in the various specialties of medicine. The ABMS was formed in 1934 as a joint advisory board by 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. This institution has gradually evolved to finally include 24 medical specialty boards, including the ABNM. The ABMS establishes a series of standard principles and provides regulation and oversight of all medical specialty boards. In the early 2000's, working with ACGME, the 24 medical specialty boards reached a consensus on the common clinical competencies that should be expected of all trainees.(2) 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.
2. **Medical Knowledge** about established and evolving biomedical, clinical, and cognate sciences as well as the application of this knowledge to patient care.
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.
4. **Interpersonal and Communication Skills** that result in the effective exchange of information and collaboration with patients, their families, and other health care professionals.
5. **Professionalism**, as manifested through a commitment to carrying out professional responsibilities, adherence to ethical principles, and sensitivity to patients of diverse backgrounds.
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. (2)

The preliminary approach from ACGME was to introduce these competencies into the program requirements and let the programs begin to develop the means to teach and evaluate the competencies. (Figure 3) However, as the data was received by evaluating trainees along these areas was received; competency-based evaluation became a source of concern and confusion for both program directors and residents. (2) There was no real way for the learner/trainee to innovate and become a part of the solution. As these metrics were also a top-down and somewhat static evaluation for trainees in a very dynamic environment, it became clear that the trainees graduating from programs were not always ideally suited to join the workforce as independent stakeholders. Redesign of competency instruction and evaluation has been a source of debate for over the past decade. Numerous changes have been made, most recently as an attempt to integrate the competencies into the current scheme of milestones-based training.

For Nuclear Medicine, there are unique challenges. As is now obvious, the change into milestones based training at the time where the training pathway itself is evolving has been and will continue to be a difficult task. Again, the definition of these milestones and the ideal training environment to implement these changes is a moving target.

ACGME and Milestones-based training

Every specialty has created a Milestone-based training as competency-based learning and assessment tool as part of the Next Accreditation System (NAS). These data acquired in this program will be employed in the evaluation and as a source of feedback to residents and will be a measure of programs' educational effectiveness. (Figure 4) (5, 6) The main goal in defining the Nuclear Medicine Milestones was to establish an adequate amount and diversity of Milestones that would be extensive and valid for all programs and would provide important and useful information that would make the Milestones practical.

The Nuclear Medicine Milestone Working Group was formed with wide representation of the members of the Nuclear Medicine community involved in graduate education such as the ACGME staff, the Nuclear Medicine RRC, the ABNM, the Academic Council/Program Directors Association of the SNMMI, as well as resident representatives. The group drafted a preliminary document including detailed definitions of relevant subcomponents (sub competencies) in the 6 domains of general competence based on the ACGME Nuclear Medicine program requirements, the ABNM standards, and the published literature on nuclear medicine training. (2, 5) Levels of performance expected of trainees were established with an especial emphasis on integration into the duration of the education curriculum which varies from 1 to 3 years depending on the prior training of the resident. This is a unique circumstance for Nuclear Medicine. Therefore it is common to see trainees enrolling into a program at different levels and advancing at different rates. The target was to create a balance between general and specific Milestones along with scenarios for each Milestone subcomponent along with appropriate representative examples. (5)

Members of the working group and 6 program director volunteers contributed in a pilot process that involved field testing to obtain valuable feedback about the usefulness of the Milestones, under conditions similar to actual practice in the NAS. The final pilot document reduced the number of Milestones from 31 to 19 by removing duplicate items and consolidating others in every competency category. The distribution of the 19 Nuclear Medicine Milestones across the 6 general competencies is shown in the Figure 5. The Nuclear Medicine Milestones are intended to serve as a semiannual assessment of resident performance and reporting to the ACGME to provide points of reference to identify which residents are not progressing as expected. The goal of the project is to confirm that trainees are capable of providing high-quality and safe medical practice by the time of their graduation which is reflected in the Level 4 Milestones, the level designated as the graduation target. Those residents who achieve the Level 4 Nuclear Medicine Milestones should be ready for unsupervised practice. (5)

The Nuclear Medicine Clinical Competency Committee (CCC) should ideally be composed of a widely representative membership consisting of core medical faculty, technical and other nonphysician that would contribute on specific evaluation. These committee members are asked to reach a consensus decision on the assessment of each resident at each reporting time point. Guidance to aid reliable ratings and education of the residents at each Milestone level is intended to reinforce the assessment and develop a better feedback process. (5)

Current Status of U.S. Training Pathways

In the United States, radioisotope imaging and therapy are practiced as a subspecialty by diagnostic radiologists and as a specialty by NM physicians. Nuclear Medicine training can be completed through 3 different ACGME pathways with either ABR or ABNM certification. (7) Figure 6

Diagnostic Radiology (DR)

Radiologists obtain their certification in DR from the ABR. DR residency consists of 4 years in which trainees gain clinical experience with all imaging modalities, including CT, MR, NM, ultrasonography, and fluoroscopy and radiography. NM is part of DR training with a minimum requirement of 4 months that include training with planar gamma camera imaging, single-photon emission CT (SPECT), and PET, including the hybrid imaging modalities SPECT/CT and PET/CT, along with radioisotope therapy. (7)

Nuclear Radiology

Radiologists obtain their certification in NR from the ABR. NR requires an additional year in which the radiologist gains experience and knowledge in advanced radioisotope imaging and therapy during DR fellowship. NR and NM are similar in terms of clinical practice and requirements. However, NR represents a wider multimodality background whereas NM has more detailed focus on therapies. Nevertheless efforts have been made to align these program requirements by the DR-RRC. (7)

Nuclear Medicine

Nuclear Medicine physicians obtain their certification in NM from the ABNM. After a year of internship, a physician must spend 3 years in an NM residency program. If they are board-eligible or qualified in a non-DR specialty, then the requirement is for 2 years. A DR trainee can also do 1 year either before or after DR training in an NM program, and thus will be eligible for ABNM or ABR NR certification. This flexibility arises, at least in part, because the vast majority of academic NM programs are part of Radiology departments, and many trainees have had or will have Radiology training. (7)

Molecular Imaging (MI)

Molecular imaging is a rising biomedical imaging field of great potential and growing multidisciplinary clinical importance and is incorporated into DR, NR, and NM training programs although, currently MI has no ABMS certification program. MI integrates traditional 2-D and 3-D imaging systems that provide excellent anatomical and physiologic information, with the use of a wide range of both radioisotope and non radioisotope methodologies to study the spatiotemporal distribution of molecular or cellular processes for biochemical, biologic, diagnostic, or therapeutic applications. (7, 8) PET/CT and SPECT/CT are already well-known examples of these hybrid technologies and PET/MRI represents an innovative path for diagnostic imaging that will incorporate the advantages of physiologic function from PET with soft-tissue contrast and characterization from MR. (7) Non-radioisotope technologies (e.g. optical imaging) are experiencing rapid progress and will soon be a part of the everyday clinical practice and will provide physiologic information particularly relevant in oncology.

Alternate pathways

A training pathway leading to dual certification in DR and NM would be a perfect combination to acquire in-depth knowledge in both NM and cross-sectional imaging. This will also help graduates from this pathway to find jobs, since the dual pathway DR/NM residencies should be attractive for future trainees and this should provide a stable flow of graduates with full training and expertise in these modalities. Although the ACGME does not accredit new combined programs, a resident can accomplish dual training by doing a fellowship in NM after a DR residency or doing a DR residency after NM residency.(9)

There are 2 practical models for combined training in DR and NM. In one of the models, the DR trainee completes 16 months of the DR residency to NM training with possibility of using 2 months from the internship for NM. The 16 months must be completed in the same institution that has to support both a DR residency and either an NM residency or a nuclear radiology (NR) fellowship recognized by the ACGME. There are 43 programs in NM and 20 in NR that meet the requirements according to a recent survey conducted between late 2013 and early 2014. Nine DR programs already offer this pathway, and another 5 are considering it. (9, 10)

The second approach is a five-year program, integrating NM and DR. This has been successfully done at the University of Iowa and elsewhere. At Stanford University a slightly different approach has been implemented. It includes a second postgraduate year (PGY-2),

with NM and research, after the internship year. PGY-3, 4, and 5 each have 11 months of DR and 1 month of NM, and finally PGY-6 consists of NM and research.

Although both 4-year and 5-year pathways present limitations, the benefits of combined programs is evident and ABNM has made changes in the eligibility criteria to support these programs. For example, 6 months of consecutive training in NM are not necessary anymore, and trainees can dedicate up to 2 months of elective time in any subspecialty of DR considered appropriate by the residency director. Trainees can be eligible for the ABNM examination at sites with either NR or NM training programs, provided that the cumulative time devoted to NM training is adequate and other necessities are met. ABR and ABNM are determined to work together to meet the demands of the workforce and to sustain growth in the field of NM/molecular imaging. (9)

International Nuclear Medicine (with a focus on Europe)

Nuclear Medicine was recognized as a specialty in only a few countries in Europe in the 1970s. Germany was the leading country, and they created the Society of Nuclear Medicine-Europe (SNME), and accepted memberships from other European countries. A separate group, the European Society of Nuclear Medicine (ESNM) was formed and headquartered in Vienna, and included all European countries where the practice of Nuclear Medicine was recognized as a specialty. The kick-off meeting of this society took place in 1974 and its main goal was the recognition of the training programs and in allowing free circulation of doctors among countries. However it took another decade until both the German (SNME) and the European counterpart (ESNM) merged after much discussion in 1985 into the European Association of Nuclear Medicine (EANM). Today it embodies the practice of Nuclear Medicine across all European Countries regardless of their EU membership status. Since its establishment, it has pursued the scientific development of the specialty in Europe. (11)

Another organization, the European Union of Medical Specialist (UEMS) provides education and sets standards for healthcare practice throughout Europe. It was founded in 1958 in Brussels, even before the birth of the EU and is a multinational organization embodying 40 medical specialist committees with links to the EU secretariat. After a long administrative process, the EU admitted Nuclear Medicine as a new specialty in 1989. The following year the Nuclear Medicine Specialist Committee of the European Union of Medical Specialists was created in Amsterdam, consisting of 2 delegates from each EU country where Nuclear Medicine was recognized. The committee has been meeting annually in a different country each year. Statutes of a new European Board of Nuclear Medicine were created at the 1993 meeting and were ratified the following year. The first meeting of the Board took place in Paris in 1995, reaching an agreement on recommendations for postgraduate training, although each individual country was still entitled to make their own decisions regarding the specific aspects of training (11)

The EANM has also founded a European School of Nuclear Medicine (ESNM) with the aim to motivate and standardize educational activities in all countries through training and educational courses. However to this date, there is no broad European policy on Nuclear

Medicine. Currently the European Association of Nuclear Medicine (EANM) and the professional organization of the Union of the Medical Specialists/ Section of Nuclear Medicine (UEMS) are trying to standardize the training. Although each country has their own training system, a minimal training time of 4 years is compulsory for all national training programs. Another significant accomplishment was the recognition of diplomas and free movement of doctors within the EU and to the countries of the European Free Trade Agreement (EFTA). In order to ascertain some level of organization in these national training programs, the UEMS considered that minimal standards of quality should be defined to assure the overall quality of training and thereby facilitate exchange of doctors between countries. Consequently, Nuclear Medicine and other specialties have proposed to create European Boards. For the moment this certification, which can only be obtained after having worked 3 years as a specialist, is non-compulsory and does not interfere directly with the policies of each country although may be helpful in the careers of some young specialists. (12)

Future Nuclear Medicine Training Pathways

ABR/ABNM task force draft proposal

Nuclear Medicine has excelled in its use of radioisotopes for assessing organ function. In recent years, molecular imaging has emerged to allow the characterization of these processes at the cellular and subcellular levels. Thanks to the advent of hybrid techniques which unite anatomic and functional imaging such as PET/CT and SPECT/CT, assessment of function has improved remarkably. At the same time, the advancement in the technique has resulted in a need to increase training to provide the skills needed to practice. Therefore supplementary training in anatomic imaging has become necessary for NM physicians while radiologists, who are already well trained in anatomic imaging, have had to receive additional training in functional imaging. (12)

The rising use and success of radioisotopes for therapy has resulted in a requirement for more training in this area for both radiologists and NM physicians. Throughout the last 20 years DR and NM have kept their own separate pathways in training programs and have achieved a predominance in anatomic and in functional imaging, respectively (2). This has led to a multiplicity of training pathways accredited by 2 different ACGME residency review committees (RRCs), and with multiple pathways to certification offered by 2 separate American Board of Medical Specialties boards. As a result of this, the experience and range of skills of trainees has experienced considerable variation.(13) In order to face this broad variation in residency training, the ACR and the SNM, agreed to work together to define the issues and seek solutions by identifying the intrinsic differences and limitations. As a result, a Task Force on Nuclear Medicine Training was formed with members of both societies with wide experience in Radiology and NM training, including the Radiology and NM RRCs, the ABR and the ABNM, as well as the ACR and the SNM. (13) Four work groups with members of both NM and radiology organizations were established to carry out the objectives of the task force, the RRC work group, the board certification work group, the training pathway work group, and the economics work group. These groups reached a strong consensus and finally reported their conclusions and recommendations in a summary

document. (13) There was general agreement that in the future it was likely that molecular imaging would be practiced by physicians who are dually certified by the ABR and the ABNM, and that more training in anatomic and functional imaging will be necessary to reach full proficiency for future radiologists and NM physicians. The recommendations of the task force are summarized in Figure 3. (13)

Nuclear Medicine/ Molecular Imaging Diagnostic Exams

A pressing, but unanswered question for the future of Nuclear Medicine/Molecular Imaging is not only who is interpreting the exams but also what types of exams will be utilized and which exams will drive value based imaging in the future. Healthcare reform in the United States is focused on improving quality, efficiency, and the patient experience. The determination of imaging and resource utilization appropriateness criteria for each patient by nuclear medicine physicians is critical to the establishment of a new standard. (14) The role of nuclear medicine in patient management continues to increase as a result of collaboration with other radiology specialties and referring physicians. A multidisciplinary approach to personalized medicine facilitates appropriate use determination of available imaging techniques and leads to the development of novel hybrid imaging applications in nuclear medicine. (15) Report turn-around times and access to images for physicians and patients has also contributed to clinical management pre and post-intervention.

The evolution of hybrid SPECT/CT, PET/CT and PET/MR has improved diagnostic quality and patient throughput while providing institutions with effective resource utilization options. (Figures 7 and 8) Clinical indications, novel radioisotopes and radioisotope availability are factors that affect the determination of the appropriate hybrid technology. Patient throughput should also be considered. Most low-medium energy procedures take longer to perform with SPECT/CT than PET/CT. The following are examples:

- Tc99m bone scan without SPECT, 3-4 hours total patient time compared to 2 hours total time for 18F-NaF Bone PET.
- Nuclear stress SPECT Stress/Rest imaging, 3-4 hours total patient time compared to 1 hour for Myocardial Perfusion PET Imaging.
- Indium-111 OctreoScan, 2-3 hours per day on successive days compared to 2 total hours with Ga68 Dotatoc.

Hybrid technology acquisition costs vary, but generally a SPECT/CT is \$750,000-\$2,000,000, PET/CT \$1,500,000-\$3,500,000, and a PET/MR \$4,000,000+. Maintenance costs may run \$200,000-\$1,000,000 per year depending on the complexity of the technology. Managers should consider equipment and maintenance costs, procedure types and duration, staffing, room utilization, radioisotope costs, administrative, and institutional overhead when determining an ROI.

The majority of approved nuclear medicine diagnostic procedures currently utilize low-medium energy radioisotopes. However, NH_3 Ammonia and Rb^{82} offer PET options in cardiology, and ^{18}F -NaF in skeletal imaging through the National Oncologic PET Registry (NOPR). The latter may see approval in the foreseeable future. There are an abundance of

research PET radioisotopes in the pipeline including iodine-124, fluorine-18, carbon-11, gallium-68, and zirconium-89. Global shortages of molybdenum-99 may impact the availability of low-energy radioisotopes and lead to increased utilization of PET with current alternatives or result in fast-track approval of new PET radioisotopes to meet the demand.

Within this data one can glean many important trends for the utilization of Nuclear Medicine examinations and perhaps more can be stated from an understanding of the reimbursement pattern for these exams and the potential for change with approvals of investigational radiopharmaceuticals in the near future. While FDG PET/CT has been the driver of Molecular Imaging training by virtue of the overall volume of studies and reimbursement for at least a decade prior to 2012, it is clear that there is again change in the near future. While some within imaging specialties and those specialties that refer to imagers have become accustomed to the information, value and even pattern of uptake in an FDG PET/CT, this change rapidly with the onset of technologies many of which are explored in this issue of the Seminar's in Nuclear Medicine. It is then incumbent upon those who will be stewards of this change to recognize the expertise needed to maintain the value equation of these examinations. There will be additional types of Cardiac, Neurological and Oncologic examinations that will require that the practitioner have a very close relationship with information. This information will most likely be generated by the patient, referring physician as well as the images themselves. The level of communication to arrive at this value equation is scarcely described in the competencies and milestones in a way that translates into those currently practicing the art and considering the additional skillset required to keep pace with the developments around the corner.

Conclusion

Change is inevitable in medical practice and training. In the last decade, this has been clearer with the changing landscape of medicine, hospital-based practices, private practice and other stakeholders. The formation of Nuclear Medicine gives us information about the future of Nuclear Medicine. When there were few credentialing organizations and templates for practice this drove innovation as well as the need for the formation of entities that best described the practice of Nuclear Medicine. In some ways, the draft proposals for the further collaboration of fusion of the ABNM and ABR, there is again room for innovation as we consider what type of skills would best describe the most skilled as well as credentialed practitioner of this art. In fact some aspects of Molecular Imaging that were difficult to append to the "Goals and Objectives" of a Nuclear Medicine rotation rider may be stated more clearly in the creation of some new entity of the future. In fact, some of the pathways needed for the approved, reimbursed future examinations in Nuclear Medicine can be championed by the trainees and junior diplomats of this nascent field to preserve the practice rather than fragment it among many traditionally non-imaging specialties. Perhaps this will help to overcome the weaknesses in current Nuclear Medicine and Radiology training programs while synergizing their strengths to achieve excellence in a promising future together.

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Figure 1.
Timeline of events and foundation of different institutions with significant relevance in the history of Nuclear Medicine training.

Figure 2.

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 and the trend has been stable ever since. Modified from a figure that was originally published in JNM.. Graham MM, Metter DF. Evolution of nuclear medicine training: past, present, and future. J Nucl Med. 2007;48(2):257-68.© by the Society of Nuclear Medicine and Molecular Imaging, Inc.

Clinical competency	Task	Program					
		3 y			2 y		1 y
		Year 1	Year 2	Year 3	Year 1	Year 2	1 y
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	✓	✓	✓	✓	✓	✓
Medical knowledge	8. Maintain procedure logs	✓					✓
	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		✓			✓	✓
Interpersonal and communication skills	7. Attend CT and MRI conferences	✓	✓	✓	✓	✓	✓
	8. Participate in journal clubs	✓	✓		✓	✓	✓
	9. Take ABNM in-service examination	✓	✓	✓	✓	✓	✓
	1. Learn to dictate	✓			✓		✓
	2. Learn to use Word and Power Point	✓			✓		✓
	3. Understand need for accurate communication	✓			✓		✓
	4. Participate in NM consultations	✓	✓	✓	✓	✓	✓
Professionalism	5. Participate in intra- and interdepartmental conferences	✓	✓	✓	✓	✓	✓
	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	✓	✓	✓	✓	✓	✓
	6. Become familiar with practice performance guidelines	✓	✓	✓	✓	✓	✓
Practice-based learning and improvement	7. Become familiar with ABNM MOC process	✓		✓	✓	✓	✓
	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		✓	✓	✓	✓	✓
Systems-based practice	7. Become familiar with ABNM MOC process	✓		✓	✓	✓	✓
	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	✓	✓	✓	✓	✓	✓

Figure 3.

Summary of clinical competencies that need to be learnt according to the 3 different programs. This table was originally published in JNM. Graham MM, Metter DF. Evolution of nuclear medicine training: past, present, and future. J Nucl Med. 2007;48(2):257-68. © by the Society of Nuclear Medicine and Molecular Imaging, Inc.

ACGME Milestone Project: Primary Stakeholders and Benefits	
Stakeholder	Benefit
Accreditation Council for Graduate Medical Education	Accreditation—continuous monitoring of programs; lengthening of site visit cycles Public accountability—report at a national level on competency outcomes Community of practice for evaluation and research, with focus on continuous improvement
Certification boards	Potential use—ascertain whether individuals have demonstrated qualifications needed to sit for board exams
Residency program	Guide curriculum development More explicit expectations of residents Support better assessment Enhanced opportunities for early identification of under-performers
Residents	Increased transparency of performance requirements Encourage resident self-assessment and self-directed learning Better feedback to residents

Figure 4.

ACGME Milestones: Primary Stakeholders and Benefits. Reprinted with permission This table was originally published in JNM. Edgar L, Fig LM. ACGME Milestone Project. J Nucl Med. 2012;53(4):15N © by the Society of Nuclear Medicine and Molecular Imaging, Inc.

Competency	No. of Milestones	Milestone Categories
Medical Knowledge	7	<ul style="list-style-type: none"> Physiology and Pathophysiology Anatomic Imaging Instrumentation Radiopharmaceuticals and Molecular Agents Medical Physics, Mathematics, and Radiation Biology Regulatory Requirements Radiation Protection, Patient Safety, and Procedural Safety
Patient Care	5	<ul style="list-style-type: none"> Diagnostic: General Nuclear Medicine, Cardiovascular, and Molecular Imaging (Patient Evaluation, Procedure Selection, Monitoring, and Interpretation) Cardiovascular Nuclear Medicine-Stress Testing: Patient Evaluation and Procedure Monitoring Therapy: Radiiodine for Benign Thyroid Disease—Patient Evaluation, Procedure Selection, Procedure Performance, and Follow-Up Therapy: Radiiodine for Thyroid Malignancy—Patient Evaluation, Procedure Selection, Procedure Performance, and Follow-Up Therapy: Parenteral—Patient Evaluation, Procedure Selection, Procedure Performance, and Follow-Up
Practice-Based Learning and Improvement	2	<ul style="list-style-type: none"> Self-Directed Learning and Understanding Scientific Studies Implements Quality Improvement Project
Interpersonal and Communications Skills	2	<ul style="list-style-type: none"> Patient Communications Health Care Team
Professionalism	1	<ul style="list-style-type: none"> Professional Ethics and Accountability
Systems-Based Practice	2	<ul style="list-style-type: none"> Computer Systems Economics

Figure 5.

Distribution of the 19 Nuclear Medicine Milestones across the 6 general competencies. This table was originally published in JNM. Fig LM, Edgar L. Nuclear medicine milestones. Journal of graduate medical education. 2014;6(1 Suppl 1):116-8. © by the Society of Nuclear Medicine and Molecular Imaging, Inc.

Table 1. ACGME residency programs and positions for the 2011-2012 academic year

Accredited Residency Programs	Programs With Approved Positions	Approved Programs Residing Within Radiology Departments	Approved Positions	Filled Positions	Positions Filled by Radiologists	Programs With No Trainees
Diagnostic radiology residency	187	187	4,890	4,671	NA	0
Nuclear radiology fellowship*	19	19	35	19	19	5
Nuclear medicine residency*	54	51†	201	144	20†	3

Source: Accreditation Council for Graduate Medical Education [5].
 Note: NA = not applicable.
 *Seven institutions support both nuclear radiology and nuclear medicine programs, with 11 and 14 trainees, respectively; 5 share the same program director.
 †Personal communications with respective program coordinators and/or program directors, December 2011.

Figure 6.

Examples of ACGME residency programs and positions for the 2011-2012 academic year. This table was originally published in JNM. Edgar L, Fig LM. ACGME Milestone Project. J Nucl Med. 2012;53(4):15N © by the Society of Nuclear Medicine and Molecular Imaging, Inc.

Figure 7.

In 2014, an estimated 1,616,900 clinical PET scans (excluding research studies) were performed in 2014 in 2,355 hospital and non-hospital sites with fixed units or using mobile services. Since 2011, total PET patient scans decreased 14% from an estimated high of 1,853,700 in 2011 to an estimated 1,594,100 in 2013, with a slight 1% increase to the current estimate of 1,616,900 patient scans in 2014. Reprinted with permission, 2014 PET Benchmark Report, IMV Medical Information Division

Figure 8.

A. Of the 1,616,900 clinical PET/CT and PET scans performed in 2014, 93% (1,510,800) were for oncology studies, 4% (61,500) were for cardiology studies, and 3% (42,400) were for neurology studies. A negligible 0.3% (2,200) scans were other types of PET scans. **B.** Of the PET scans performed in 2014, 98% were performed on adults and 2% were performed on pediatric patients. **C.** In 2014, 97% of all PET scans were performed on an outpatient basis and 3% were for inpatients. Reprinted with permission. 2014 PET Benchmark Report, IMV Medical Information Division