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EDITORIAL

# Hybrid training in nuclear medicine: where are we going to?

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Over the past decades, nuclear medicine has rapidly evolved from a specialty using gamma camera's and positron emission tomography (PET) into a hybrid imaging branch in health care. The introduction of PET/CT and SPECT/CT scanners has boosted research and development in many areas of interest, such as oncology, cardiology, neurology, and orthopedic surgery. The combination of anatomical and functional imaging has definitely improved the diagnosis of patients and the understanding of pathophysiological phenomena. Recent introduction of PET/MR in clinical practice will further improve imaging of brain disorders, whereas its role in oncology is still being studied. Oncology is the most frequently reported indication for PET/CT and [18F]F-FDG the most commonly used radiopharmaceutical [1]. Radiolabeled PSMA ligands are expected to become the second most used tracer in clinical practice. Remarkably, the European Society of Radiology (ESR) and the European Association of Nuclear Medicine (EANM) [2] also noted in their joint paper that a full diagnostic CT as part of a PET/CT scan was reported in a minority of indications. The reporting of hybrid imaging studies shows much more heterogeneity: In many institutes, this is done by nuclear medicine physicians, but in some hospitals, this is done by radiologists or other specialists. The number of dual specialists reported in that paper was extremely small, a situation that could limit the application of the hybrid techniques. Therefore, both societies stated that an interdisciplinary training program would improve the situation. Papers by Beyer et al. [3] and Graham et al. [4] recommended already in the past improving training programs and harmonizing reporting methodology to improve the adoption of all hybrid imaging techniques. Their international survey also found that more than 72% of the responders underlined the lack of hybrid experts in their country. In 2017, Mankoff [5] raised the discussion of the need for modernization of the training programs for radiologists and nuclear medicine physicians. Multidisciplinary training is the cornerstone of future practice of medicine. In most countries, however, this was and is still not the case. Gatidis et al. [6] showed that in three countries, nuclear medicine was not a separate specialty, while training in nuclear medicine as part of a radiology program varied from 1 to 27 months. In six countries, partial certification in reporting PET or CT scan for radiologists and nuclear medicine physicians, respectively, was available. Finally, in 21 out of 34 countries, dual certification in both specialties is possible, but a joint training program for hybrid imaging was not available in a majority of the responders (59%).

The integration of the radiology and nuclear medicine training programs has been extensively discussed in many countries. This discussion is firstly often hampered by the fact that nuclear medicine is more than hybrid imaging. The rapid increase in radionuclide therapies has more or less overwhelmed the initial discussion. Training in this field, including dosimetry and toxicity aspects, is identified as the most important drivers for a separate specialization in nuclear medicine. The introduction of [$^{177}$Lu]Lu-DOTA-TATE and, recently, of [$^{177}$Lu]Lu-PSMA in addition to iodine-131, radio-embolization, and radium-223 has stimulated the number of treatment options in general. Compared to the number of PET/CT and SPECT/CT scans performed nowadays, RNT still comprises a minority of activities in clinical practice. Secondly, due to the reimbursement issues, not all hospitals are able to treat patients with radiopharmaceuticals. Centralization of radionuclide therapy is expected to be forced by insurance companies. For example, in the Netherlands, the total number of treatments with radionuclides per year is estimated in range from 22,500 to 25,000 [7]. The maximum number of RNT per day is 100, and with a total of about 60 hospitals having a department of nuclear medicine, it would result in 1–2 therapies per day per hospital. Since the initial costs to launch a treatment team is

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extremely high, close collaboration between nuclear medicine departments is stimulated. As a consequence, many nuclear medicine physicians will not gain any experience in RNT at all. Finally, [$^{177}$Lu]Lu-PSMA is booming business at this moment, but once there is a new treatment option with better survival rates, success stories like this will immediately stop.

## Train ing in nuclear medicine in different countries

Over the past years, several papers have been published relating to training programs in different countries. Remarkably, there is significant difference between these programs, in which the overall duration as well as the type of internships shows a great variety. The overall duration of training ranges from four (such as in Italy and Spain) to 6 years (such as in Austria and the UK). The real residency time within this training period ranges from 2 years, such as in France, to 4 years, such as in Portugal. One must realize that even during this residency time, other internships can be included too, making the variety even greater. In some countries, internships must be followed in radiology or internal medicine, whereas in other countries, these are optional and related to the field of interest of the resident. In Table 1, an overview is given of the differences between countries both within Europe and further afield.

Nuclear medicine training in the USA can be followed in different tracks all accredited by the Accreditation Council for Graduate Medical Education (ACGME). The first track, in which the educational program in nuclear medicine (NM) should be at least 36 months in length, was developed by the American Board of Nuclear Medicine (ABNM) and approved by the Society of Nuclear Medicine and Molecular Imaging (SNMMI), member of the Council of Medical Specialty Societies (CMSS) [22, 25]. This first track also requires that residents have satisfactory education in direct patient care in the first year (at least nine months) and radiology in the subsequent period. The second track is in nuclear radiology (NR), a clinical subspecialty comprising the diagnostic and therapeutic use of radiopharmaceuticals. The total length of this nuclear medicine education program is at least 12 months on top of a completed residency program in radiology. Although this so-called fellowship is remarkably shorter than the education program in nuclear medicine, nuclear radiologists are certified to perform exactly the same procedures as nuclear medicine physicians. A third track includes a 16-month training program in nuclear medicine within a 4 years residency in radiology. The fourth track entails successfully completing 3 years of Internal Medicine training after which at least 1 year of nuclear medicine is followed [26]. As a result, there is great heterogeneity in experience in the field of nuclear medicine in the USA, and this is accepted by all the boards involved including the ABNM. Biersack [27] gives a typical example of differences in vision on nuclear medicine as a specialty worldwide without any elaboration on pros and cons on this situation. Yet, the dramatic fall in NM residents in the USA by nearly a quarter in the last decade clearly shows the declining student interest in this field, thereby underlining the necessity to adapt education programs [28]. The competency-based learning programs that have been developed in the past in combination with the idea of lifelong learning were mainly driven by the introduction of hybrid imaging in clinical practice [23]. Based on the rapid growth of radionuclide treatment options, the training duration was increased from 2 to 3 years. In a later paper by Mankoff [5], combined training was indicated as highly important to stimulate further developments in molecular imaging and theranostics. Consequently, a multidisciplinary approach was regarded as most relevant with even expansions into radiotherapy and cardiology.

In a paper by Paez et al. [29] on the situation of nuclear medicine in the Middle East, it was mentioned that almost 1200 nuclear medicine physicians were working in this area at that time of publication. The overall period of education and training ranges from 4 to 5 years. Apparently, with the introduction of hybrid imaging, radiologists are more and more attracted in this specialty. In Turkey, the total residency time is 4 years, comprising a thorough training in nuclear medicine and rotations in radiology for 2 months, endocrinology for 1 month, and cardiology for 1 month. This program is completed with a written thesis and an oral examination.

## Training in the Netherlands

Initially, the idea of education in nuclear medicine was to extend this period with 1 year training in radiology revealing a total of 5 years instead of the 4 years. However, in 2013, the Dutch Society of Radiology (NVvR) and the Dutch Society of Nuclear Medicine (NVNG) decided to combine the two educational programs into one. The most important driver behind this concept was the rapid growth in hybrid imaging techniques, such as PET/CT, SPECT/CT, and PET/MR. In addition, the overall idea was a lifelong learning concept, in which a thorough basic education program forms the basis for further learning in clinical practice in specific sub specializations. In this new "Curriculum Opleiding Radiologie en Nucleaire Geneeskunde" (CORONA), the overall education period for this joined program indeed extended from four to 5 years [30]. The first 2.5 years, the so-called common trunk, comprises of education in all 8 themes, such as abdominal, breast, and cardiothoracic radiology as

**Table 1** Overview of programs of education in nuclear medicine in several countries

| Country | Year of publication | Author [reference] | Overal years of training | Nuclear medicine (years) | Comments |
|---|---|---|---|---|---|
| Austria | 2013 | Leitha [8] | 6 | 4.0 | 1 year internship in internal medicine, 1 year in another specialty (radiology is optional) |
| Czech Republic | 2014 | Kaminek et al. [9] | 5 | 3.0 | 2 years internships in internal medicine and radiology |
| France | 2013 | Gremillet et al. [10] | 4 | 2.0 | 4 semesters in associated clinical specialties |
| Germany | 2014 | Freudenberg et al. [11] | 5 | 3.5 | 1 year in clinical inpatient care and 6 months in another field (optional) |
| Italy | 2015 | Ciarmiello et al. [12] | 4 | | Internships not further specified; cross training with radiology is present (81 out of 300 credits) |
| The Netherlands | 2023 | NVvR-NVNG [13] | 5 | 2.0 | The first 3 years of training in radiology includes education in basic EPA's in nuclear medicine |
| Poland | 2014 | Teresinska et al. [14] | 5 | 3.25 | 12 months internship in radiology, 3 months in cardiology, endocrinology and oncology |
| Portugal | 2013 | Vieira et al. [15] | 5 | 4.6 | 1 year internship in internal medicine, 3 months in radiology, and 1 month in cardiology |
| Spain | 2013 | Soriano Castrejon et al. [16] | 4 | 2.0–3.0 | Program is under reconstruction: 2 years common trunk with radiology, 2–3 years specialization |
| Sweden | 2019 | Sverriges Läkarförbund [17] | 5–7,5 | 2.5 | Nuclear medicine is a subspecialty of clinical physiology, radiology or oncology that can be following during or after specialization |
| Switzerland | 2020 | SIWFfmh-ISFM [18] | 5 | 3.0–4.0 | Internships up to 2 years in radiology and 1 year in another specialty (endocrinology, cardiology, etc.) |
| Turkey | 2017 | Ozcan et al. [19] | 4 | 3.6 | 4 months rotations in radiology (2 months), endocrinology (1 month), and cardiology (1 month) |
| UK | 2016 | Neilly et al. [20] | 6 | 3.0 | 3 years core radiology training |
| Australia and New Zealand | 2022 | RACP [21] | 6 | 3.0 | The Royal Australasian College of Physicians (RACP) program: basic training has to be completed |
| | | RANZCR | 6 | 2.0 | Royal Australian and New Zealand College of Radiologists (RANZCR) program: at least 4 years training in radiology |
| USA | 2022/2011 | ACGME/Frey et al. [22, 23] | | 3.0 | American Board of Nuclear Medicine certified program |
| | 2022/2017 | ACGME/Segall et al. [22, 24] | 4 | 1.3 | American Board of Radiology certified program |

well as nuclear medicine and molecular imaging. During these 2.5 years, a total of 8 weeks is assigned to learning the basics of NM. The second 2.5 years are called the differentiation phase where each resident chooses 1 or 2 of the eight available themes. If NM is chosen, the resident follows 18 months of training in this field with the rest of the 2.5 years dedicated to maintaining general competencies and on-call duties. In the end, all residents are registered as radiologist, irrespective of the differentiation followed. In fact, the chosen differentiation is not officially registered. The new generation of nuclear medicine physicians are now called nuclear radiologist. The integration of education

programs including the common trunk followed by a differentiation track was embraced by many clinicians. The obvious benefit is that one dedicated specialist can be contacted instead of two for readings, advice, multidisciplinary meetings, etc. Two of the major drawbacks of this training strategy are the limited time left for nuclear medicine in general (18 months) and the experience in radionuclide therapy in particular. This new education program was supported by the Dutch federation of medical specialists (FMS) and the college of medical specialties (CGS). Because of these drawbacks, a new curriculum has been developed with the major advantage that the overall exposure to nuclear medicine has increased significantly. Three years, the so-called basic radiology period, are spent in becoming proficient in all basic "entrustable professional activities" (EPAs), including NM. With this, the official criteria of category 1 or 2, chapter 3, of the Institutional Program Requirements of the International Atomic Energy Agency will be met [31]. An additional two years can be spent to dedicated training in nuclear medicine and molecular imaging, with which category 3 of the IAEA requirements will be met. A training center, either as single institute or in collaboration with other centers, should offer enough diagnostic and therapeutic procedures in order to be able to meet all required EPAs in this field. This new program was recently launched under the name Opleiding Radiologie en Nucleaire Geneeskunde (ORANGE). With a lifelong learning strategy as the backbone, residents can still apply for additional fellowships in radionuclide therapy, hybrid imaging, or other aspects of nuclear medicine and molecular imaging after their official registration as young specialist.

## Pros and cons of hybrid training

Over the past years, the new training program in radiology and nuclear medicine in the Netherlands has been regarded as innovative on the one hand, but conflicting on the other. This idea of training in hybrid imaging as a basis for the educational program, with a lifelong learning strategy as overall design, was developed by two national societies. The original idea, the so-called CORONA track, had to be adapted and also adopted by the two societies because of the international IAEA requirements. With the reshaped track, called ORANGE, the new generation of (nuclear) radiologists may better fulfill the clinical demands where hybrid imaging or imaging in a specific topic, like cardiology or neurology, is core business. Since all subspecialized radiologists, including nuclear radiologists, share common interests and are part of the same specialism, they will share a bright, collaborative future from this perspective. In addition, cardiothoracic radiologists and nuclear radiologist, for example, may be a better counterpart for cardiologists and radiation oncologist, respectively, than in earlier times. The presence of a national society of nuclear medicine (NVNG) ensures that the nuclear radiologist will remain responsible for hybrid imaging and remain involved in research and new developments, as well as strategic plans in general. The contribution to the new educational program was well balanced and ultimately agreed upon by all members of the Dutch Society of Nuclear Medicine. The Dutch Society for Radiologists accepted a clear, not to be discussed role for nuclear medicine in this program. In addition, the understanding of each other's position has improved clearly. The ultimate question, however, should not be what it means for the new generation of specialists, but what it means for the patients. This latter question cannot be answered yet, as more time is required to find out whether the current curriculum should be adapted again or not. The idea that cardiologist, pulmonologists, or other specialists could be certified for reading hybrid images is a concept embraced in the USA, but not in Europe.

Looking at the overview in Table 1, it is clear that most, if not all, countries comply with the IAEA guidelines. Yet, education in nuclear medicine throughout the world, including Europe, shows a large variety in the curricula or education programs. Some have implemented clinical rotations; others have focus on radiology. In this respect, the questions to be answered are as follows: Where are we going? What are we looking for, What is common practice? What is the best for our patients? Radionuclide therapy is currently booming business, but what happens if and when better targeted treatment options become available, as happened with Zevalin in the treatment of B cell lymphoma? How do we proceed with hybrid techniques and specialists who have undergone no/limited hybrid training? From a historical and future perspective, hybrid imaging can be regarded as strong backbone of nuclear medicine with radionuclide therapy on top of it. Should we empower the concept of a common trunk curriculum in hybrid imaging, with a specialization in radionuclide therapy for those who have interest as well as the opportunity to work in this field? A hybrid imaging specialist with thorough knowledge of nuclear medicine working with diagnostic radiopharmaceuticals can potentially bridge the gap observed in clinical practice nowadays. In depth, knowledge of radionuclide therapy may not be essential in this. Now is the time to discuss our ultimate goal and the framework to achieve this. Waiting any longer to harmonize training programs or curricula within Europe may lead to bigger problems. We certainly should not allow the accreditation boards of other specialties to decide what will happen with nuclear medicine, as can be observed in countries outside Europe.

In the Netherlands, we are looking forward to the next generation of hybrid imagers in the hope that they will fill the gap currently observed in clinical practice, while only a portion of these nuclear radiologists will dive into radionuclide therapies.

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## Declarations

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