Review Article

CURRENT TRENDS IN NUCLEAR PHARMACY PRACTICE

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ABSTRACT

Nuclear Pharmacy seeks to improve and promote the public health through the safe and effective use of radioactive drugs for diagnosis and therapy. A nuclear pharmacist, as a member of the nuclear medicine team, specializes in the procurement, compounding, quality control testing, dispensing, distribution, and monitoring of radiopharmaceuticals. In addition, the nuclear pharmacist provides consultation regarding health and safety issues, as well as the use of non-radioactive drugs and patient care. The main objectives of this review are to discuss the development of nuclear pharmacy, education, regulations and role of nuclear pharmacist in the nuclear pharmacy practice.

Keywords: Nuclear Pharmacy, Nuclear Pharmacist, Radiopharmaceuticals, Non-radioactive drugs.

INTRODUCTION

Nuclear Pharmacy involves the preparation of radioactive materials that will be used to diagnose and treat specific diseases. It was the first pharmacy specialty established in 1978 by the Board of Pharmaceutical Specialties. Nuclear pharmacy seeks to improve and promote health through the safe and effective use of radioactive drugs for not only diagnosis but also therapy.

The operation of the modern nuclear pharmacy, or radio pharmacy, is a complex business, balancing elements of patient care with radiation safety. Nuclear pharmacist's compound radiopharmaceuticals for diagnostic imaging and therapy while providing oversight to packaging, radiation safety and transportation operations. The availability of this service is, for many physicians, a cost-effective and necessary part of their practices. Sync or International Corporation operates an expanding network of over 120 domestic and nine international pharmacy service centers. The company compounds and dispenses patient-specific unit dose radiopharmaceutical prescriptions for use in diagnostic imaging and therapy and provides a complete range of advanced pharmacy services. Syncor services over 7,000 customers and is the only national pharmacy network of its kind that provides a combination of diagnostic, therapeutic and information services to hospitals and alternative site markets[1].

HISTORY AND DEVELOPMENT OF NUCLEAR PHARMACY

The early history of nuclear pharmacy is tied together with nuclear medicine. Henri Becquerel was discovered naturally occurring radioactivity. George de Hevesy introduced the tracer principle. Hermann Blumgart and Soma Weiss performed the first application of radioactive tracers in medical research in a study of the velocity of circulating blood in 1925.

Abbott Laboratories sold the first radioactive drug in 1950. The advent of the Tc-99m generator and the design of the "scintillation camera" by Hal O. Anger in the 1950's were important events leading to the growth in nuclear medicine which was greatly increased by the introduction of the gamma camera and the commercial availability of the Tc-99m generator in 1964. This was followed by the rapid development in Tc-99m radiopharmaceuticals. These events and others set the stage for the emergence of nuclear pharmacy as a specialty practice and the creation of the Section on Nuclear Pharmacy in 1975.

Pharmacists had been encouraged to become involved with radioactivity used in medicine years long before the formation of the Section on Nuclear Pharmacy. William H. Briner and John E. Christian had written articles and contributed in other ways to set the stage for the emergence of nuclear pharmacy.

William Briner started the N.I.H. Radiopharmacy in 1958. He trained many pharmacists that contributed to the development of nuclear pharmacy and established principles and procedures important to the assurance of quality radiopharmaceuticals. Fall, 1947, he developed the first formal lecture and laboratory courses in the United States for teaching the basic principles of radioisotope applications. He published and spoke at national meetings on the importance of pharmacy involvement in radioisotope research and applications in medicine. He was responsible for the first monographs for individual radiopharmaceuticals in the U.S.P. John Christian and William Briner were both active on key national committees responsible for the development, regulation and utilization of radiopharmaceuticals.

In the early 1970's several nuclear pharmacy practitioners and educators met at meetings related to nuclear medicine and radiopharmaceuticals. They believed that the need existed for the development of an organization that would allow pharmacy practitioners serving nuclear medicine to come together for the betterment of pharmacists and services to nuclear medicine. In 1978, a

document entitled "Nuclear Pharmacy Practice Standards" was accepted by the Section on Nuclear Pharmacy. The practice standard document then became the basis for the development of documentation requesting recognition as a specialty by the Board of Pharmaceutical Specialties (BPS). The petition was approved by the BPS in 1978 and nuclear pharmacy became the first formally recognized pharmacy specialty practice in the world.

In order to develop procedures necessary to award board certification in nuclear pharmacy, the BPS appointed a Council on Nuclear Pharmacy. The council was determined requirements for eligibility, prepare an examination, set scores for passing and, finally, administer an examination. The examination was developed based upon the practice standards and with several approaches to assure an examination would meet the standards necessary for national board certification. The first examination for Board Certification in Nuclear Pharmacy (BCNP) was given to 72 pharmacists on April 24, 1982. The BPS officially designated 63 as BCNP on August 25, 1982. In 1998, there were over 430 BCNP in the U.S.

Starting with a small number of practitioners and educators, nuclear pharmacy has increased in services as well as in number of practitioners. The advent of the concept of a commercial centralized nuclear pharmacy that was initiated in 1972 has resulted in the establishment of several hundred centralized nuclear pharmacies that provide the greater part of radiopharmaceuticals used in the U.S[2].

TYPES OF NUCLEAR PHARMACY

There are essentially two different kinds of nuclear pharmacy services called Institutional Nuclear Pharmacy and Commercial Centralized Nuclear Pharmacies:

Institutional Nuclear Pharmacy is most likely operated through large medical centers or hospitals.

Commercial Centralized Nuclear Pharmacies provide their services to subscriber hospitals. They prepare and dispense radiopharmaceuticals as unit doses that are then delivered to the subscriber hospital by nuclear pharmacy personnel.

EDUCATION AND CERTIFICATION IN NUCLEAR PHARMACY[2]

Eligibility Requirements

The minimum requirements for certification in nuclear pharmacy are:

- Graduation from a pharmacy program accredited by the Accreditation Council for Pharmacy Education (ACPE) or program outside the U.S. that qualifies the individual to practice in the jurisdiction. Foreign trained pharmacists must pass the Foreign Pharmacy Graduate Examination Committee (FPGEC) examination.
- Current, active license to practice pharmacy in the U.S. or another jurisdiction
- 4,000 hours of training/experience in nuclear pharmacy practice
- Achieving a passing score on the Nuclear Pharmacy Specialty Certification Examination

Required training

There are certain precautions that must be taken into account when handling radiopharmaceutical materials on a daily basis. Nuclear pharmacists receive extensive training on the various radiopharmaceuticals that they use. They are trained in radiation safety and other aspects specific to the compounding and preparation of radioactive materials. Many things are required to become pharmacists, but to become a nuclear pharmacist one must go through the following training:

1. 200 hours of classroom training in basic radioisotope handling techniques

specifically applicable to the use of unsealed sources is required. The training should consist of lectures and laboratory sessions in the following areas:

- Radiation physics and instrumentation
- Radiation protection
- Mathematics of radioactivity
- Radiation biology
- Radiopharmaceutical chemistry

2. 500 hours in handling unsealed radioactive material under a qualified instructor is also required. This experience should cover the type and quantities of by-product material requested in the application and includes the following:

- Ordering, receiving, surveying, and unpackaging radioactive materials safely.
- Calibration of dose calibrators, scintillation detectors, and survey meters
- Calculation, preparation, and calibration of patient doses including the proper use of syringe shield

EDUCATIONAL APPROACHE[3-6]

Early Education Programs

Nuclear pharmacy has been recognized as a specialty practice for over 20 years. The field has changed from a few innovative pharmacists with advanced degrees located in larger hospitals to a network of centralized commercial nuclear pharmacies located in cities across the USA. Various educational approaches have been developed to provide the knowledge base required to work in a nuclear pharmacy (Table 1).

Table 1: Early Education Programs[10]

Tracer methodology courses developed at Purdue University in 1947 by John E. Christian
Radioisotope course for pharmacists in 1955 by Philadelphia College of Pharmacy and Philadelphia Hospital Pharmacists
Six 2-h sessions offered by the Oregon Society of Hospital Pharmacists in 1958
''Radioisotopes in Modern Pharmaceutical Practice,'' a series of lectures by Manuel Tubis, University of Southern California, 1960
''Basic Radiological Health for Pharmacists,'' cosponsored by the PHS and ASHP in 1963

Elective Series in the First Professional Degree

The pharmacy student may obtain the fundamental knowledge necessary to enter nuclear pharmacy through a series of elective courses while completing a first professional degree program. There are several advantages to this approach. The student learns the material at a reasonable pace with a degree of repetition and reinforcement. The student may have an opportunity to gain practice experience through a summer internship or as part of an externship have been exposed to of the negative and positive aspects of nuclear pharmacy practice. The student may discontinue the elective series at anytime. Thus, at graduation a student entering nuclear pharmacy has a high probability of retention. A student that does not complete the entire series of elective courses can still benefit from a greater understanding of the importance of diagnostic imaging in pharmaceutical care and drugs associated with procedures.

Postgraduate Short Courses

Although several pharmacy schools offer nuclear pharmacy education at the undergraduate level, there are not sufficient numbers of qualified practitioners available. The course may be structured to last five to six consecutive weeks at a training site or for two-week intervals followed by practice in a nuclear pharmacy for a total of six weeks of a certificate program where the trainee uses videotapes and workbooks for self-study while working in a nuclear pharmacy followed by a two-week session at the school of pharmacy.

Short courses are offered by universities, private corporations or by a centralized nuclear pharmacy corporation to their employees only. The short courses are available to licensed pharmacists that wish to elect a career change and enter nuclear pharmacy practice. The advantages to the pharmacist are a relaxed admission criteria and minimal time commitment compared to a graduate program or a residency in nuclear pharmacy.

Master of Science Degree

Some pharmacists elect a MS degree program as a means to enter nuclear pharmacy practice. The MS degree allows considerable opportunity for the pharmacist to become well schooled in the knowledge base needed for practice as well as the development of basic research skills. During the period of 1.5-2.0 years required to accomplish the requirements of an MS degree, the pharmacist relinquishes immediate earning potential during training. However, the scope of the practice is expanded through preparation to conduct research. The added knowledge gained through the MS degree allows the pharmacist to participate in teaching and increases the potential for employment in a large medical center. A MS degree program may be directed to the more traditional practice of nuclear pharmacy or emphasize the preparation, dispensing and clinical applications of radiopharmaceuticals used for Positron Emission Tomography (PET) imaging.

Recertification

Recertification for Board Certified Nuclear Pharmacists (BCNP) is a three-step process:

- Self-evaluation: Review of the nuclear pharmacy practice activities/functions that have changed since initial certification or last recertification
- Peer review: Documentation of nuclear pharmacy practice activities over the seven year certification period, which are then reviewed by the Specialty Council on Nuclear Pharmacy
- Formal Assessment: This assessment of a practitioner's knowledge and skills will be accomplished through one of two methods: 1) achieving a passing score on the 100-item, multiple-choice objective recertification examination, based on the content outline of the certification examination; OR 2) earning 70 hours of continuing education credit provided by a professional development program approved by BPS. A current, active license to practice pharmacy is required for recertification.

REGULATIONS OF NUCLEAR PHARMACY

Regulation of nuclear pharmacy practice[2] has a fairly complex history due largely to the dichotomous nature of radiopharmaceuticals, which are viewed as both radioactive materials and as drug products. Nuclear pharmacy practice, being highly technical and specialized, has presented a rather unique challenge to the state boards of pharmacy. The National Association of Boards of Pharmacy (NABP) has assumed a leadership role in assisting individual state boards with guidelines in this area. The NABP has published *Model Regulations for Nuclear Pharmacy,* a document that was developed and is maintained through timely revisions in consultation with the FDA, NRC, pharmacy professional organizations, and individual practicing nuclear pharmacists. One important

part of these regulations is the recognition of a *Qualified Nuclear Pharmacist.* A recent vision of the NABP Model Regulations contains the following definition:

A *Qualified Nuclear Pharmacist* signifies a pharmacist who holds a current license issued by the Boards, and who is either certified as a nuclear pharmacist by the Board of Pharmaceutical Specialties or satisfies each of the following requirements:

1. Meets minimal standards of training for status as authorized user of radioactive material, as specified by the Nuclear Regulatory Commission.

2. Has successfully completed a minimum of 200 contact hours of instruction in nuclear pharmacy, safe handling and use of radioactive material from a nationally accredited college of pharmacy, or other training program recognized by the Nuclear Regulatory Commission, with the minimum 200 hours apportioned as follows:

a. radiation physics and instrumentation (85 hours)

b. radiation protection (45 hours)

c. mathematics pertaining to the use and measurement of radioactivity (20 hours)

d. radiopharmaceutical chemistry (30 hours)

e. radiation biology (20 hours)

3. Has attained a minimum of 500 hours of clinical nuclear pharmacy training under the supervision of a qualified nuclear pharmacist in, but not limited to, the following areas, as described in the current Nuclear Pharmacy

Practice Standards:

a. procuring radioactive materials

b. compounding of radiopharmaceuticals

c. performing routine quality control procedures

d. dispensing radiopharmaceuticals

e. distributing radiopharmaceuticals

f. implementing basic radiation protection procedure

g. consulting and educating the nuclear medicine community, patients, pharmacists, other health professionals, and general public.

4. Has submitted an affidavit of experience and training to the Board. The NRC revised its regulations to recognize an Authorized Nuclear Pharmacist who is defined to be a pharmacist:

a. Has current board certification as a nuclear pharmacist by the Board of Pharmaceutical Specialties or

b. 1. Has completed 700 hours in a structured educational program.

2. Has obtained written certification.

PRACTICE OF NUCLEAR PHARMACY

The practice of nuclear pharmacy[2] is composed of several domains related to the provision of nuclear pharmacy services. These domains, determined by formal task analyses, serve as the basic structure for the Nuclear Pharmacy Practice Guidelines. The nine general domains involved in nuclear pharmacy practice are

1. Procurement
2. Compounding
3. Quality assurance
4. Dispensing
5. Distribution
6. Health and safety
7. Provision of information and consultation
8. Monitoring patient outcome
9. Research and development

Procurement of radiopharmaceuticals and other drugs, supplies, and materials necessary for nuclear pharmacy practice involves determining product specifications, initiating purchase orders, receiving shipments, maintaining inventory, and storing materials under proper conditions.

Compounding of radiopharmaceuticals involves a wide variety of activities ranging from relatively simple task such as reconstituting reagent kits with Tc-99m sodium pertechnetate to complex tasks such as operating a cyclotron and synthesizing F-18 fluorodeoxyglucose. Compounding of Positron Emission Tomographic (PET) radiopharmaceuticals requires more extensive controls and validation procedures than those for Tc-99m-based radiopharmaceuticals; hence a supplemental document entitled *Nuclear Pharmacy Guidelines for the Compounding of Radiopharmaceuticals for Positron Emission Tomography* has been developed.

Quality assurance of radiopharmaceuticals involves performing the appropriate chemical, physical and biological tests on radiopharmaceuticals to ensure the suitability of the products for use in humans. Radiopharmaceuticals must meet all specifications described in their respective USP monographs, including such parameters as radionuclidic purity, radiochemical purity, chemical purity, pH, particle size, sterility, bacterial endotoxin, and specific activity.

Dispensing of radiopharmaceuticals occurs upon the receipt of a valid prescription or drug order from an authorized physician. They are dispensed to hospitals or clinics for administration to patients by trained health professionals. Radioactive decay between preparation and dispensing time and between dispensing and administration times must be taken into account. Radiopharmaceuticals also subjected to special labeling requirements such as inclusion of the standard radiation symbol and the words *Caution-Radioactive Material.*

Distribution of radiopharmaceuticals within an institution is subject to institutional policies and procedures, generally involving lead-lined boxes or other shielded containers labeled with identifying information. Distribution of radiopharmaceuticals from a centralized nuclear pharmacy to other institutions is subject to local,

state, and federal regulations, including those promulgated by states boards of pharmacy, the Department of Transportation (DOT), and the Nuclear Regulatory Commission (NRC). These requirements generally related to packaging, labeling, shipping papers and record keeping.

Health and safety are crucial elements of nuclear pharmacy practice. Radiation safety standards, including limits for radiation doses, levels of radiation in an area, concentrations of radioactivity in air and waste water, waste disposal and precautionary procedures have been established and are enforced by the NRC.

Provision of information and consultation is a highly important function of nuclear pharmacists. Employing both oral and written communication skills, nuclear pharmacists convey their expert knowledge to Physicians, technologists, other pharmacists, patients and others.

Monitoring Patient Outcome is an important component in the concept of pharmaceutical care. Within the scope of his or her practice, a nuclear pharmacist can assist in

- Ensuring that patients are appropriately referred to nuclear medicine
- Developing institutional standards for the rational use of radiopharmaceutical and ancillary medications and conducting drug use evaluation for these drugs.
- Prospectively screening patients regarding appropriate use of radiopharmaceuticals and ancillary medications.
- Evaluating the safety and efficacy of radiopharmaceutical and ancillary medications.
- Ensuring that patients receive proper preparation prior to receiving radiopharmaceuticals and ancillary medications.
- Ensuring that appropriate interventions are used to enhance nuclear medicine procedures.
- Ensuring that clinical problems associated with the use of radiopharmaceuticals or ancillary medications are prevented or recognized, investigated, and rectified.
- Monitoring the safety and efficacy or outcomes of individual patient's drug regimes, surgical interventions, and other therapeutic measures using imaging modalities and radiometric technology.
- Administering diagnostic and therapeutic radiopharmaceuticals, ancillary medications and performing nuclear medicine procedures.
- Ensuring that information gained through the use of diagnostic radiopharmaceuticals is included as an integral component of a patient's therapeutic care plan.

Research and Development of new radiopharmaceuticals and clinical applications are vital for the viability and future growth of nuclear medicine and the nuclear pharmacy profession. Nuclear pharmacist involvement may include participation in the development of new radiopharmaceuticals, including product design and laboratory testing. Similarly, nuclear pharmacists may participate in developing new compounding procedures or quality-control testing methods for existing radiopharmaceuticals. A frequent area of nuclear pharmacy involvement is participation in clinical trials of investigational radiopharmaceuticals. In addition, nuclear pharmacists often serve as members on institutional radiation safety and radioactive drug research committees.

GUIDELINES FOR NUCLEAR PHARMACY PRACTICE

Primary tasks listed in the American Pharmacists Association's Nuclear Pharmacy Practice Guidelines include:

- Order, receipt, storage and inventory control of radioactive drugs (radiopharmaceuticals), other drugs used in nuclear medicine, and related supplies
- Preparation of radiopharmaceuticals by combining radioisotopes with reagent kits, and compounding radiopharmaceuticals that are not commercially available
- Functional checks of instruments, equipment and devices and determination of radiopharmaceutical quality and purity
- Filling of prescription orders
- Packaging, labeling and transport of radiopharmaceuticals
- Proper handling of hazardous chemicals and biological specimens
- Communicating radiopharmaceutical related information to others
- Assuring that patients receive proper preparation before radiopharmaceutical administration and trouble-shooting unanticipated outcomes
- Laboratory testing of new radiopharmaceuticals, new compounding procedures, quality control methods and participation in clinical trials

ROLE OF NUCLEAR PHARMACIST IN NUCLEAR PHARMACY PRACTICE[7-8]

When a particular radioactive material was needed, a trained nuclear pharmacist was available to prepare the product and dispense it to the end user. When you look at a nuclear pharmacy, its operation is not much different than that of a traditional pharmacy - a "prescription" for a particular product is presented, and the nuclear pharmacist must prepare and dispense that "prescription". Where a traditional pharmacist will

dispense doses in milligram weight units, a nuclear pharmacist will dispense in mill curie activity units. Where a traditional pharmacist dispenses tablets and capsules, a nuclear pharmacist dispenses the radioactive material in liquid or capsule form. Where a traditional pharmacist will generally dispense the prescription to the patient, the nuclear pharmacist will dispense to a hospital or clinic nuclear medicine department where the dose will be administered to the patient.

Nuclear pharmacists are available to provide drug information to other health professionals, to aid the nuclear medicine staff in the selection of products, and to assist in the interpretation of unusual studies. Nuclear pharmacists receive extensive training on the various radiopharmaceuticals that are used, as well as training on the safe handling of radioactive materials and the procedures that will minimize radiation exposure to themselves and to others[9].

Nuclear pharmacists serve as vital links in the provision of nuclear medicine services. By working closely with the nuclear medicine staff, nuclear pharmacists can contribute a tremendous amount to the provision of care for the patients who are undergoing nuclear medicine procedures. While similar to traditional pharmacy, nuclear pharmacy is also in many ways unique, and can be a challenging and rewarding carrier choice for pharmacists.

CONCLUSION

Nuclear pharmacy is a specialized practice of pharmacy focusing on radiopharmaceuticals[10]. The nuclear pharmacist is an expert in a specific class of drugs but also must remain current on all medications employed in the treatment of disease, especially those used for interventional studies, those that potentially interfere with nuclear medicine procedures, and those whose effectiveness may be monitored by nuclear medicine studies.

The specialty practice of nuclear pharmacy has been instrumental in leading pharmacy into the development and the recognition of specialties in pharmacy. The dedication of early pioneers and the support of professional pharmacy organizations have been of great significance in the development of nuclear pharmacy to the degree of excellence experienced today.

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REFERENCES

1. Murphy D, Nuclear Pharmacy Primer, Radiation Protection Management, 20(5), 2003, 18-27.
2. Gennaro AR, Remington: The Science and Practice of Pharmacy, 20th Ed, Vol 2nd, Lippincott Williams & Wilkins, 2000, p.1781-1790.
3. Shaw SM, Approaches to Education in Nuclear Pharmacy, American Journal of Pharmaceutical Education, 59, 1995, 296-298.
4. Ice RD, Shaw SM, Born GS, George RE, Nuclear Pharmacy Education, American Journal of Pharmaceutical Education, 38, 1974, 420–425.
5. Lipman AG, Specialization in Pharmacy Education: Resources and risks, American Journal of Pharmaceutical Education, 54, 1990, 381-382.
6. Grussing PG, Allen DR, Callahan RJ, Cooper JF, Ice RD, Kalman SH, et al. Development of pharmacy's first specialty certification examination: Nuclear pharmacy, American Journal of Pharmaceutical Education ,47, 1983, 11-18.
7. Ahluwalia B, Allen EW, Basmadjian G, Ice RD, The role of nuclear pharmacy in reducing radiation exposure, Health Physics, 40, 1981, 728–729.
8. Briner WH, Radiopharmacy: the emerging young specialty, Drug Intellectual, 2, 1968, 8–13.
9. Christian JE, Radioactive isotopes in hospital pharmacy, Bulletin of American Society for Hospital Pharmacy, 7, 1950, 178–83.
10. Shaw SM, Ice RD, Nuclear Pharmacy, Part I: Emergence of the Specialty of Nuclear Pharmacy, Journal of Nuclear Medicine Technology, 28(1), 2000, 8-11.

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