Radioactive! Nuclear Pharmacy or Unclear Pharmacy?

Kevin Hope, RPh
Radioactive! Nuclear Pharmacy or Unclear Pharmacy?

ACTIVITY DESCRIPTION
Nuclear Pharmacy has long been a misunderstood professional segment of the pharmaceutical sciences, from patients and professionals alike. This session is intended to provide a general overview of the practice of nuclear pharmacy, including highlights of commonly used nuclear medicine imaging agents. Special considerations, including equipment and safety concerns, are addressed as they apply to this unique professional practice.

TARGET AUDIENCE
The target audience for this activity is **pharmacists**, **pharmacy technicians** and **nurses** in hospital, community, and retail pharmacy settings.

LEARNING OBJECTIVES
After completing this activity, the **pharmacist** will be able to:
- Identify the source of commonly used radioisotopes for medical imaging
- Explain the advantages of nuclear medicine over other imaging modalities
- Identify key radiation safety practices of nuclear pharmacy practice
- Identify the functionality of the most common nuclear medicine radiotracers

After completing this activity, the **pharmacy technician** will be able to:
- Identify the source of commonly used radioisotopes for medical imaging
- Explain the advantages of nuclear medicine over other imaging modalities
- Identify key radiation safety practices of nuclear pharmacy practice
- Identify the functionality of the most common nuclear medicine radiotracers

ACCREDITATION
Pharmacy
PharmCon, Inc. is accredited by the Accreditation Council for Pharmacy Education as a provider of continuing pharmacy education.

Nursing
PharmCon, Inc. is approved by the California Board of Registered Nursing (Provider Number CEP 13649) and the Florida Board of Nursing (Provider Number 50-3515). Activities approved by the CA BRN and the FL BN are accepted by most State Boards of Nursing.

CE hours provided by PharmCon, Inc. meet the ANCC criteria for formally approved continuing education hours. The ACPE is listed by the AANP as an acceptable, accredited continuing education organization for applicants seeking renewal through continuing education credit. For additional information, please visit: [http://www.nursecredentialing.org/RenewalRequirements.aspx](http://www.nursecredentialing.org/RenewalRequirements.aspx)

Universal Activity No.: 0798-0000-17-172-H04
Credits: 1.5 contact hour (0.15 CEU)

Release Date: 1/21/2018
freeCE Expiration Date: 1/21/2020
ACPE Expiration Date: 7/21/2020

ACTIVITY TYPE
Knowledge-Based Home Study Webcast

FINANCIAL SUPPORT BY
Pharmaceutical Education Consultants, Inc.
ABOUT THE AUTHOR
Kevin T. Hope, RPh is a Clinical Education Specialist with the PharmCon team in Conway, SC. Kevin began his career in pharmacy at an early age and has practiced as a pharmacist in a variety of settings, beginning with a retail pharmacy experience at Eckerd Drug Corporation in York, SC. Kevin transitioned from a retail setting to a Charleston, SC nuclear pharmacy setting in 2002, where he practiced for over 13 years. Kevin has served as an adjunct faculty member for the South Carolina College of Pharmacy, having coordinated and instructed the college’s ‘authorized user’ program for nuclear pharmacy. In addition, Kevin has direct experience in the education of pharmacy technicians, having directed the pharmacy technology program at Horry Georgetown Technical College in Myrtle Beach, SC prior to joining the PharmCon team.

Kevin has received several professional awards, including the Pfizer Leadership Award and the Innovative Pharmacy Practice Award from the South Carolina Pharmacy Association. Having served as a corporate communications trainer for Triad Isotopes, Kevin has presented to a variety of audiences, including a nuclear pharmacy symposium at the American Pharmacists Association annual meeting. Kevin has served as an independent editor for several Paradigm Publishing textbooks, and currently serves on the professional advisory board for Paradigm Publishing. Kevin's passions lie in helping students achieve and surpass personal educational goals.

FACULTY DISCLOSURE
It is the policy of PharmCon, Inc. to require the disclosure of the existence of any significant financial interest or any other relationship a faculty member or a sponsor has with the manufacturer of any commercial product(s) and/or service(s) discussed in an educational activity. Kevin Hope reports no actual or potential conflict of interest in relation to this activity.

Peer review of the material in this CE activity was conducted to assess and resolve potential conflict of interest. Reviewers unanimously found that the activity is fair balanced and lacks commercial bias.

Please Note: PharmCon, Inc. does not view the existence of relationships as an implication of bias or that the value of the material is decreased. The content of the activity was planned to be balanced and objective. Occasionally, faculty may express opinions that represent their own viewpoint. Participants have an implied responsibility to use the newly acquired information to enhance patient outcomes and their own professional development. The information presented in this activity is not intended as a substitute for the participant’s own research, or for the participant’s own professional judgement or advice for a specific problem or situation. Conclusions drawn by participants should be derived from objective analysis of scientific data presented from this activity and other unrelated sources.

Neither freeCE/PharmCon nor any content provider intends to or should be considered to be rendering medical, pharmaceutical, or other professional advice. While freeCE/PharmCon and its content providers have exercised care in providing information, no guarantee of its accuracy, timeliness or applicability can be or is made. You assume all risks and responsibilities with respect to any decisions or advice made or given as a result of the use of the content of this activity.
Radioactive!
Nuclear Pharmacy or Unclear Pharmacy

Objectives

• Identify the source of commonly used radioisotopes for medical imaging
• Explain the advantages of nuclear medicine over other imaging modalities
• Identify key radiation safety practices of nuclear pharmacy practice
• Identify the functionality of the most common nuclear medicine radiotracers
Nuclear Pharmacy: So, What Exactly Is That?

Central Concept

• Identify agents that are known to localize or behave in a specific manner within an organ system.
  • "Tag" that agent with a radioactive tracer
  • Inject the "tagged" agent
  • View the progress of the "tagged" agent using a specialized camera ("gamma camera")

Umbrella Categories

**DIAGNOSTIC**
- Myocardial Perfusion
- Gastric Emptying Time
- Gallbladder functionality
- Infection Localization
- Cerebral Perfusion
- Bone Imaging
- Thyroid Uptake
- Renal Imaging

**THERAPEUTIC**
- Iodine -131
- Yttrium-90
- Palladium-103

Yttrium
The Nuclear Pharmacy Staff

• **Nuclear Pharmacists**
  • Hold a valid pharmacists license
  • ‘Authorized User’ Training for Radioactive Materials
  • Board Certification (optional)
  • Florida carries additional licensing & CE requirements for nuclear pharmacists

• **Nuclear Pharmacy Technicians**
  • Requirements vary drastically from state to state
  • Professional training programs
  • ‘Authorized User’ Training for Radioactive Materials

The Nuclear Pharmacy Staff

• **Facilities Engineer**
• **Radiation Safety Officer (RSO)**
  • Maintains regulatory documentation

• **Delivery Drivers**
  • Become a primary “face” of the pharmacy
  • Specific D.O.T. training
Why Nuclear Medicine?

CT

NUCLEAR

Photo: http://www.texasheart.org/HIC/Topics/Dxag/dinuc.cfm

Diagnostic Nuclear Medicine FUNCTION
The radiotracer, injected into a vein, emits gamma radiation as it decays. A gamma camera scans the radiation area and creates an image.

Primary Radiotracer Sources

NUCLEAR REACTOR

- Molybdenum-99 (Mo-99)
  - decays to technetium (Tc99m)
- Iodine 131
- Xenon-133
Primary Radiotracer Sources

Mo-99 > Tc99m Generator

• *Small in size*
• Shipped inside lead shielding
• Tc-99m collects on an aluminum column & is rinsed off with normal saline

Primary Radiotracer Sources

CYCLOTRON

• Thallium-201
• Indium-111
• F-18 (FDG)
Working With ‘Melting Ice’

Time is of the essence!

**HALF LIFE**

- Delivery Issues
- Dosing Issues
- Inventory Issues
- Staffing Issues

Delivery Issues
Dosing Issues

Inventory Issues
Staffing Issues

Compounding the Radiotracer

- USP 797
- State Board of Pharmacy Regulations
- Hazardous Materials Regulations (NRC, or designee)
- Department of Transportation Regulations (shipping/receiving radioactive materials)
- Employee Safety
- Public Safety
“Doctor David Banner: physician, scientist; searching for a way to tap into the hidden strengths that all humans have. Then an accidental overdose of gamma radiation alters his body chemistry. And now, when David Banner grows angry or outraged, a startling metamorphosis occurs.”

Incredible Hulk, opening theme
Employee Safety

• TIME
• DISTANCE
  • Doubling the distance from a source reduces exposure to one fourth!
• SHIELDING

Employee Safety: Shielding

• Shielding of Gamma Radiation
  • Lead
  • Titanium
• Shielding of Beta Radiation
  • Plastic
• Syringe shields
  • “Pigs”
Employee Safety: Monitoring

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Radiation Worker, Annual Limits:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Body</td>
<td>5 rem</td>
</tr>
<tr>
<td>Lens of the Eye</td>
<td>15 rem</td>
</tr>
<tr>
<td>Extremities</td>
<td>50 rem</td>
</tr>
<tr>
<td>Embryo / Fetus of worker</td>
<td>0.5 rem</td>
</tr>
</tbody>
</table>

How much is too much?

Body Badge
Finger Ring Badge

https://www.dm.usda.gov/ohsec/radiodosimetry.htm

Employee Safety – Relative Risk

<table>
<thead>
<tr>
<th>Activity</th>
<th>Risk of Fatality:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking one cigarette</td>
<td>1 death : 7,229,270 cigarettes smoked</td>
</tr>
<tr>
<td>Driving on roads in North America</td>
<td>1 death : 17,857,143 miles driven</td>
</tr>
</tbody>
</table>

1 rem of radiation exposure = risk of driving 8,929 miles

1 rem of radiation exposure = risk of smoking 3,650 cigarettes

Recall: The annual occupational exposure limit is 5 rem

Patient Safety – Relative Risk

<table>
<thead>
<tr>
<th>Nuclear Medicine Procedure</th>
<th>Effective Dose (in rem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac Stress Test (rest/stress) Tc99m sestamibi</td>
<td>1.28</td>
</tr>
<tr>
<td>Lung perfusion &amp; Ventilation Tc99m MAA &amp; Xe-133</td>
<td>0.25</td>
</tr>
<tr>
<td>Gallbladder Scan Tc99m disofenin</td>
<td>0.31</td>
</tr>
<tr>
<td>Tc-99m labeled white blood cells</td>
<td>0.81</td>
</tr>
<tr>
<td>PET scan F-18 FDG</td>
<td>1.41</td>
</tr>
</tbody>
</table>


Common Nuclear Medicine Agents: Cardiovascular

- Thallium-201
- Tc99m Sestamibi (Cardiolite®)
- Tc99m Tetrafosmin (Myoview®)

  “Nuclear Stress Test”
  - Myocardial perfusion
  - Ejection fraction
Common Nuclear Medicine Agents: Bone

- Tc99m medronate (MDP®)
- Tc99m oxidronate (HDP®)
- Tumor metastasis to bone
- Pain of unknown origin

Common Nuclear Medicine Agents: Lung

**Pulmonary Ventilation**
- Tc99m-DTPA
- Xe-133 gas

**Pulmonary Perfusion**
- Tc99m-MAA (microaggregated albumin)
- Pulmonary Embolism
- COPD
Common Nuclear Medicine Agents: Gallbladder

- Tc99m mebrofenin (Cholotec®)

Gallbladder function
Agent mimics bile

Common Nuclear Medicine Agents: Gastric Emptying Time

Tc99m Sulfur Colloid

- Gastroparesis
- Gastric Dumping
Common Nuclear Medicine Agents: Lymphoscintigraphy Mapping

- Tc99m Sulfur Colloid
- Tc99m Tilmanocept (Lymphoseek®)

Detection of ‘sentinel node’

Common Nuclear Medicine Agents

**RENAL STUDIES**
- Tc99m MAG-3

**BRAIN IMAGING**
- Tc99m exametazime (Ceretec®)
- Tc99m bisicate (Neurolite®)
Common Nuclear Medicine Agents: F-18 FDG

• F-18 FDG
  “radioactively labeled sugar”
  - areas of high metabolism

Positron Emission Tomography (PET)

PET Radiopharmaceuticals

MANUFACTURING vs. COMPOUNDING

Food and Drug Administration (FDA)
  - submission of an ANDA
  - GMPs
  - stringent traceability

• F-18 FDG
• Sodium Fluoride
PET Radiopharmaceuticals

Positron Emission Tomography

- 511 keV energy
- Half life of F-18: ~110 minutes
- Requires a different imaging modality

Future trends of PET imaging?

PET Radiopharmaceuticals

**Advantages:**
- clear, functional images

**Disadvantages:**
- Procurement costs
- Higher radiation energy than SPECT
- Supply issues
Common Nuclear Medicine Agents

**Red Blood Cell Tagging**
- Tc99m Ultratag®
- Blood volume
- Detection of Gastric Bleeding

**White Blood Cell Tagging**
- Tc99m exametazine (Ceretec®)
- In-111 oxine
- Infection of unknown origin

Quality Control In Nuclear Pharmacy

- Did the drug “tag” to the radioisotope?
- Does the solution contain unwanted contaminants?
- Is the product sterile?
- Chromatography strips
  - ‘bound vs. unbound product’
Disposal of Radioactive Materials

• HALF LIFE
• Decayed inside lead barrels in the pharmacy

Nuclear Pharmacy as a Career

• Compound and dispense radiopharmaceuticals per physicians prescriptions
• Perform Quality Control testing on all dispensed products
• Oversee staff of pharmacy technicians, lab workers, and drivers
• Comply with all state and federal requirements for handling and shipment
  of radioactive material
• Provide clinical support for customers with radiopharmaceutical questions
• Provide instruction for pharmacy and nuclear medicine technology students

Nuclear Pharmacy Resources

- Purdue University
  - https://nuclear.pharmacy.purdue.edu/what.php
- Board of Pharmacy Specialties
- University of Arkansas
  - http://nuclearpharmacy.uams.edu/default.asp

Sources Cited

- Photo: http://www.texasheart.org/HIC/Topics/Diag/dinuc.cfm
Exam Questions:

1. Molybdenum-99 decays to ____ , a popular radioisotope for medical imaging with a half life of approximately 6 hours.
   a. Thallium
   b. Indium
   c. Technetium
   d. Iodine

2. One distinct advantage that nuclear medicine offers over other imaging modalities is:
   a. A clearer anatomical picture on nuclear medicine images
   b. Lower patient radiation exposure than with ultrasound imaging
   c. Elimination of the need for USP 797 guidelines, as the radiation itself serves as a sterilizing agent
   d. The ability to ascertain the functionality of a targeted organ system

3. Nuclear pharmacy personnel commonly use shielding made from ____ to shield gamma radiation from radiotracers such as technetium.
   a. Lead
   b. Plastic
   c. Paper
   d. Fiberglass

4. Doubling one’s distance from a radioactive source:
   a. Decreases exposure to one fourth
   b. Decreases exposure to one half
   c. Increases exposure by 50%
   d. Increases exposure by 100%

5. Which of the following agents is most appropriate for use in a nuclear medicine myocardial perfusion study?
   a. Tc99m Sulfur Colloid
   b. Tc99m Medronate
   c. Tc99m Sestamibi
   d. Tc99m Mebrofenin
6. **Free, unbound, technetium can be expected to accumulate in the:**
   a. Brain
   b. Pancreas
   c. Thyroid
   d. Lung

7. **Which of the following is true regarding requirements for nuclear pharmacy personnel?**
   a. Nuclear Pharmacy Technicians must attend an ASHP accredited technician program in all 50 states
   b. Nuclear Pharmacists must have additional documented training in radiation safety
   c. Nuclear Pharmacists must be board certified in nuclear pharmacy to practice in all 50 states
   d. Nuclear pharmacists are required to obtain additional CE specific to nuclear pharmacy in all states EXCEPT Florida

8. **The individual directly responsible for the nuclear pharmacy’s compliance with all safety requirements is the:**
   a. Facilities engineer
   b. Radiation Safety Officer (RSO)
   c. HIPPA Designee
   d. Head of the P&T Committee

9. **To determine whether or not radioactive contamination has been transferred to the floor of the lab, nuclear pharmacy personnel would most appropriately use a(n):**
   a. Survey meter (Geiger meter)
   b. Dose Calibrator
   c. Dosimetry Badge
   d. Metal detector

10. **A lead container in which radioactive unit doses are transported is known as a(n):**
    a. Oval
    b. Graduate
    c. Pig
    d. Dose Calibrator

11. **A nuclear pharmacy that prepares unit doses of F-18 FDG for PET scans will likely have an onsite _____ for use in production of this radiotracer.**
    a. Reactor
    b. Generator
    c. Cyclotron
    d. Transformer
12. Technetium has a half life of approximately 6 hours. A physician’s order requests a dose of 25mCi of Tc99m medronate at 1400 (2:00pm) for a nuclear medicine bone scan. The pharmacy, however, prepares this dose at 0800 (8:00am). The most appropriate amount for the nuclear pharmacy technician to draw into the syringe at 0800 (8:00am) is:
   a. 12.5 mCi  
   b. 25 mCi  
   c. 37.5 mCi  
   d. 50 mCi  
   e. Cannot be estimated from the information provided

13. The annual occupational exposure limit (whole body) for a radiation worker is:
   a. 0.5 rem  
   b. 5 rem  
   c. 5,000 rem  
   d. None of the above are correct

14. The most appropriate agent to use for a nuclear medicine pulmonary perfusion study, which measures blood supply to the lungs is:
   a. Xe-133 gas  
   b. Tc99m MAA  
   c. Tc99m tetrafosmin  
   d. Tc99m MAG-3

15. The most appropriate agent to use for a nuclear medicine pulmonary ventilation study, which measures air supply into the lungs is:
   a. Xe-133 gas  
   b. Tc99m MAA  
   c. Tc99m tetrafosmin  
   d. Tc99m MAG-3