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
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ACTIVITY TYPE
Knowledge-Based Live Webinar

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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.

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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
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

Why Nuclear Medicine?

- **CT**
- **NUCLEAR**

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

Photo: [http://www.texasheart.org/HIC/Topics/Diag/dinuc.cfm](http://www.texasheart.org/HIC/Topics/Diag/dinuc.cfm)
Primary Radiotracer Sources

NUCLEAR REACTOR

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

Primary Radiotracer Sources

CYCLOTRON

- Thallium-201
- Indium-111
- F-18 (FDG)

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

Employee Safety: Misconceptions

“Incredible Hulk, opening theme

“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>

Body Badge
Finger Ring Badge

How much is too much?

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)</td>
<td>1.28</td>
</tr>
<tr>
<td>TC99m sestamibi</td>
<td>0.25</td>
</tr>
<tr>
<td>Lung perfusion &amp; Ventilation</td>
<td>0.31</td>
</tr>
<tr>
<td>TC99m MAA &amp; Xe-133</td>
<td></td>
</tr>
<tr>
<td>Gallbladder Scan</td>
<td></td>
</tr>
<tr>
<td>TC99m disofenin</td>
<td></td>
</tr>
<tr>
<td>TC99m 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
- GastricDumping

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**

- F-18 FDG  
- Sodium Fluoride

Food and Drug Administration (FDA)

  - submission of an ANDA  
  - GMPs  
  - stringent traceability

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?*

**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?
- Chromatography strips
  - ‘bound vs. unbound product’
- Does the solution contain unwanted contaminants?
- Is the product sterile?

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