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I. General overview

Basic principles of nuclear medicine
Nuclear medicine is a method of evaluation based upon organ function rather than structure and, in this regard, is distinct in the specialty of radiology. Function may be quantified with this technique and images created are actually functional maps.

Studies are performed with radiopharmaceuticals: compounds that are administered to patients, usually intravenously (but they may also be inhaled, eaten or injected intradermally or intrathecally). These are tracers that are metabolized or excreted by specific organs. Each of these compounds contains a radioactive isotope that emits a photon of a specific energy (see Appendix). Nuclear imaging is performed via emission scanning: images are created with radiation detectors that identify photons emitted from the patient. This is in distinction to x-ray studies (plain films, CT, DEXA) which are transmission scans (photons are created in x-ray tubes and pass through the patient).

Photon emissions are recorded by the gamma camera (or other radiation detectors such as a thyroid probe, PET scanner, well counter, dose calibrator, survey meter or Geiger counter) and the input can be converted to an image (scan) or into quantitative data (number of photons detected) from which both relative and absolute data can be derived.

Nuclear medicine at Dartmouth Hitchcock Medical Center
The Division of Nuclear Medicine in the Department of Radiology is a clinically oriented service that provides all approved nuclear imaging studies. Although most of the studies are diagnostic procedures, therapy for hyperthyroidism is also provided.

There are several other nuclear studies that are provided through other services but are done in conjunction with the Nuclear Medicine Section; these include iodine, phosphorous and samarium therapy for cancer patients by the Section of Radiation Oncology.
A complete list of all Nuclear Medicine protocols is available in a digital format on the computers in the technology working area.

**Nuclear medicine residency rotation**
The American Board of Radiology requires four months of nuclear medicine training during a diagnostic radiology residency. There is, therefore, at least one resident assigned to the Nuclear Medicine all of the time. Others may rotate in nuclear medicine as well. This includes Cardiology fellows (2 months required in cardiac nuclear medicine during their fellowship), other members of the house staff on elective and medical students.

There are additional opportunities for both didactic and clinical education in nuclear medicine during the residency period. The radiology resident on call is responsible for covering emergency procedures in nuclear medicine. Nuclear medicine is also taught in the department's core curriculum teaching conferences as well as in additional conferences settings such as interesting case conferences and interdepartmental conferences.

**Resident responsibilities**
The expectations of the radiology resident covering nuclear medicine are directly related to the level of training and capabilities of that individual. The goal is for increasing responsibility during the four year period with the hope that the individual is managing the service at the level equivalent to an attending radiologist by the completion of the program.

There are several functions for which the resident will be responsible on a routine basis. These are detailed below.
**Quality assurance**
The resident will participate in the Quality Assurance program and must review the daily gamma camera quality control as well as patient examination quality control. Please see the Quality Assurance section of this manual for details.

**Readout sessions**
It is the responsibility of the resident rotating in nuclear medicine to prepare the daily readout sessions. It is the goal of this service that, whenever possible, all studies are to be interpreted and dictated on the day that they are performed. The resident should be prepared to present each case: this includes the pertinent patient history and interpretation of their examination with reference to, when appropriate, prior nuclear examinations, other radiological studies and correlative exams ordered on that day. Following the readout session, it is also the resident’s responsibility to dictate the study report (see the section on report dictation).

During the course of the resident's rotations, use of the nuclear medicine computer workstation will be learned; specifically, the resident will call up studies for review, run display macros and learn how to process cases. This will be done in conjunction with both the nuclear medicine physicians and the technologists. Most current studies are reviewed directly off the monitor.

In certain instances, a case cannot be read on the day that it is performed. Reasons for this include waiting for correlative studies and studies performed late in the day. All urgent studies receive at least a preliminary report when completed.

**Prior examinations**
The pertinent prior studies are typically retrieved from the PACS. It is the resident’s responsibility to have all pertinent examinations available for readout.

**Interacting with referring physicians**
Unexpected findings need to be reported to the requesting physician. This may be done by phone, messaging in the electronic medical record or by e-mail. Urgent findings should be reported directly to the requesting physician by phone. It is also encouraged, whenever possible, to phone results to physicians at outside institutions.

*Report approval*

Scan reports must be approved promptly. It is advisable to review and sign off on dictations on a daily basis.

*Therapeutic studies*

There are quite a few therapeutic modalities performed in nuclear medicine, but the only one performed with any frequency in Nuclear Medicine at DHMC is iodine-131 treatment of hyperthyroidism. Please refer to "Authorization and Information Sheet for Radioactive Iodine (I-131) Therapy for Hyperthyroidism." This can be found in the Policy and Procedure Manual. Iodine-131 therapy for thyroid cancer is performed by the Section of Radiation Oncology and the radiology residents do participate in there treatments.

In order for an individual to be approved and licensed to perform therapeutic studies using iodine-131, the resident must participate in at least three low dose (hyperthyroidism) and three high dose (thyroid cancer) treatment. A log of treatments should be kept by each resident. Paperwork will be provided to each resident by the Program Coordinator for submission to the ABR.

In each case, the treatment is preceded by a discussion of the procedure with the patient, allowing the patient to ask questions. Any woman of childbearing age (without a history of hysterectomy) must have a negative pregnancy test before therapy.

Each patient must sign a consent form before the treatment as well. The consent form is the last page of the information packet.
Policy and procedure manual
The Nuclear Medicine Policy and Procedure Manual is kept on the computer in the reading area as well as in the technologist work area and is also available through the Radiology website. Included in this manual are protocols for all procedures performed (including indications and patient preparation) as well as the Quality Assurance program and instructions for scheduling.

Nuclear medicine staff coverage
The interpretation of studies and the handling and administration of radiopharmaceuticals must always be performed by or under the authority of an individual named on the Medical Center's Radioactive Materials License. Physicians in the Department of Diagnostic Radiology on this license are

- Alan Siegel
- Petra Lewis
- Marc Seltzer
- Stephanie Yen
- Helene Nagy
II. Monthly goals and objectives

Rotation I

Knowledge based objectives

1. Understand the basic principles of the scintigraphic imaging. Specifically, the resident will understand what is meant by radioactive decay, activity levels, and functional imaging.

2. Be able to make preliminary interpretation of the commonly requested emergency procedures: VQ scans, GI bleeding scans and hepatobiliary scans.

3. Be able to make preliminary interpretation of the commonly requested standard procedures: bone scans, myocardial perfusion scans and FDG-PET.

4. Approve daily and weekly quality assurance procedures for the gamma camera, namely uniformity floods, energy peaks and bar phantoms.

5. Understand the principle of exponential decay and calculate doses in practical decay problems.

Technical skills

1. Be able to call up commonly performed studies for review on the workstation.

2. Be able to call up daily uniformity floods and bar phantoms for review on the workstation.

Rotation II

Knowledge based objectives

1. Understand the principles of other commonly performed nuclear medicine procedures, specifically gastric emptying studies, biliary scans for gallbladder function, gated cardiac blood pool imaging, thyroid scans, and renal scans (both clearance and cortical studies).

2. Develop a greater in depth understanding of the indications for all commonly performed nuclear medicine examinations.
3. Be able to check and approve the above listed studies upon their completion and render a preliminary reading.

4. Have spent time working side by side with the technologists in order to gain a full understanding of the commonly utilized protocols, such as performance of ventilation performance lung scans and the routine of the cardiac stress lab.

**Technical skills**

1. Be able to call up for display all routinely requested examinations, including SPECT and cine studies.

**Rotation III**

**Knowledge based objectives**

1. Understand the principles of all routinely performed studies in the Nuclear Medicine Division, including the less common procedures such as Octreoscans, gallium scans, cerebral perfusion scanning, cisternography, and adrenal imaging (mIBG)

2. Be able to check and approve the above listed studies upon their completion and render a preliminary reading.

3. Understand quality assurance procedures for a Nuclear Medicine laboratory.

**Technical skills**

1. Perform image rescaling and truncation.

2. Call up routine studies for review with pre-written display macros.


**Rotation IV**

**Knowledge based objectives**

1. Provide preliminary interpretations for all routinely performed studies in nuclear medicine.

2. Have a good understanding of therapeutic procedures performed in nuclear medicine, including radio-iodine therapy for hyperthyroidism and thyroid cancer,
Zevalin and Bexxar for NHL, P-32 therapy for polycythemia vera, hemophiliac arthropathy and peritoneal metastases, and strontium and samarium therapy for skeletal metastases.

3. Know the options for diagnostic imaging with monoclonal antibodies and be able to interpret the studies.

4. Know the basic principles of radiation dosimetry.

**Technical skills**

1. Process routinely performed SPECT examinations.

2. Have a good understanding of the operation of a nuclear cardiac stress laboratory.

3. Be able to perform iodine-131 therapies, including dose calibration and administration.

4. Have performed 3 of each of the commonly performed diagnostic nuclear medicine procedures and 10 of each of the commonly performed therapeutic nuclear medicine procedures and be eligible for licensure based upon NRC guidelines.

5. Competently be able to manage the nuclear medicine service, overseeing scheduling needs and necessary protocol changes on a patient by patient basis.
### Procedural checklist

At the beginning of the third rotation, each resident will be provided with a procedural checklist. The resident should take time during the third month to participate in each of the included procedures. The list is as follows:

<table>
<thead>
<tr>
<th>Procedure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise cardiac stress test</td>
<td></td>
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<tr>
<td>Pharmacologic cardiac stress test</td>
<td></td>
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<tr>
<td>Ventilation perfusion lung scan</td>
<td></td>
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<tr>
<td>Process tomographic study</td>
<td></td>
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<tr>
<td>Thyroid uptake measurement</td>
<td></td>
</tr>
<tr>
<td>Prepare gastric empty meal</td>
<td></td>
</tr>
<tr>
<td>Elute generator</td>
<td></td>
</tr>
<tr>
<td>Kit preparation</td>
<td></td>
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<tr>
<td>Calibrate patient dose</td>
<td></td>
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<tr>
<td>Uniformity flood</td>
<td></td>
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<tr>
<td>Bar phantom</td>
<td></td>
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<tr>
<td>Log-in radiopharmaceutical delivery</td>
<td></td>
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<tr>
<td>Room survey</td>
<td></td>
</tr>
<tr>
<td>Wipe test</td>
<td></td>
</tr>
</tbody>
</table>
IV. **Emergency coverage**

Emergency procedures are provided and are available whenever needed. There is round the clock technologist and physician coverage. Various procedures may be needed on an urgent basis, some more frequently than others. The most commonly emergency requests are VQ scans, GI bleeding scans and hepatobiliary scans.

The determination to perform a study on an emergency basis must be made by the radiologist covering the service and the requesting physician on a case by case basis. Only truly urgent studies should be performed after hours due to limited coverage and added expense. Urgent studies are those in which the results will be used to determine the immediate care of the patient. Please note that GI bleeding scans, when requested, should be performed as quickly as possible (the sensitivity of GI bleeding scans drops as the time from the episode of bleeding increases).

Once approved, the information (patient name, location, medical record number and a brief history) should be provided to the covering technologist. If the study is to be done after hours, the technologist will be listed in the weekly coverage schedule and they may be paged or called at home. If a study is requested near the end of the day and will extend after hours, it is also the resident's responsibility to pass on relevant information regarding the study to the resident who will be on call that evening.
V. Dictating

Basic structure of nuclear medicine dictations
The nuclear medicine report should consist of four parts: clinical data, study technique, findings and conclusion. The clinical data is a brief statement of the patient's problem (this is required) and, hopefully, the reason for the examination.

The technical section should be a brief description of how the examination was performed. Nuclear medicine protocols are highly variable from institution to institution and the report should record how the study was performed. *It is mandatory to include the radiopharmaceutical and dose utilized.*

The findings are the descriptive part of study: this should relay what was seen or recorded during the scan. This may include a quantitative section.

Finally, and perhaps most importantly, is the conclusion of the study. This is where the radiologist interprets that findings and states his impression. A good report will directly address the concerns of the requesting physician. In other words, answer the question being asked.
VI. Didactic Course

Core curriculum
Intro
1. Basic principles of nuclear medicine
2. Basic principles of FDG PET scanning I
3. Basic principles of FDG PET scanning II
4. Ventilation perfusion lung scanning
5. Scintigraphy of GI bleeding
6. Scintigraphy of the hepatobiliary system

Curriculum
1. Bone scans
2. Soft tissue imaging with bone agents
3. Scintigraphic evaluation of the musculoskeletal system in children
4. Evaluation of GI motility
5. Non-biliary scintigraphy of the liver and spleen
6. Scintigraphic evaluation of gall bladder function
7. Physiology and pathophysiology of the thyroid gland
8. Imaging of the thyroid gland and its disorders
9. Treatment of thyroid disease
10. Scintigraphy of the upper GU tract
11. Cystography and captopril renography
12. Imaging of infection: gallium, In-WBCs and Tc-HMPAO WBCs, peptides, IgG and anti-WBCs
13. Myocardial perfusion studies
14. Evaluation of cardiac function (MUGA, first pass and gated MIBI)
15. Scintigraphy of malignancy
16. Brain scanning and cisternography
17. Brain SPECT in the evaluation of epilepsy
18. Production and detection of radionuclides: hardware in nuclear medicine
19. Quality assurance and quality control in nuclear medicine
20. Practical problems in radioactive decay
21. Principles of internal radiation dosimetry
22. Basic principles of SPECT imaging
23. Technetium chemistry
24. Lymphoscintigraphy and shunt studies
25. Non-imaging studies: RBC mass, Schilling’s test, urea breath test, and GFR
26. Current practice of nuclear medicine: new modalities and research
VII. Quality assurance

Daily gamma camera quality control (QC) is performed with a flood source and includes uniformity and energy peaking. Each flood acquisition is reviewed visually and then quantitatively for uniformity. A flood must have a center field of view (CFOV) differential of <5%. If the camera fails this QC test, the physician in charge of nuclear medicine will determine whether imaging can continue on the system prior to service.

Patient examination quality control is, perhaps, the resident's greatest responsibility. The first step of this process is to pre-approve patient study requests. Studies are pre-approved in the Protocol section of the radiology information system (RIS). These requests are reviewed for appropriateness with the option of simply signing off on the study, requesting imaging beyond the standard protocol or changing or canceling the study. If a study is to be changed or not performed, the decision to do so should be made in conjunction with the referring physician. Any questions concerning more complex studies should be reviewed by the resident with the nuclear medicine physician.

The second portion of patient examination quality control is the review of studies upon completion of the initial set of imaging. Images or quantitative data should be reviewed for adequacy and completeness. Decisions are to be made for additional or repeat imaging based upon the images themselves as well as patient history. At this time, the resident may examine or interview the patient in order to gain additional needed information in order to optimize the current examination. Finally, the resident may request that the patient go directly for x-ray imaging in order to clarify findings on their scan.

X-rays are typically ordered in nuclear medicine for two reasons. Most often, they are done to add information needed for interpreting their nuclear scan. The typical example is using plain films to determine whether a focus of increased activity in a bone scan is due to metastatic disease or degenerative disease. X-rays are occasionally ordered in the case of a severe abnormality on a bone scan in a weight bearing region (e.g., hip). If a
large osteolytic defect is found in, for example, the femoral neck, the patient may be at a significant risk for fracture and the requesting physician should be alerted immediately.
VIII. Radiation safety

As with many of the modalities of Diagnostic Radiology, Nuclear Medicine does involve the utilization of radiation. There is a potential hazard with any level of radiation and, therefore, safety measures are required.

Patient safety
First and foremost is the safety of the patient. Studies utilizing radiation (Nuclear Medicine, plain X-ray, CT, etc) should only be performed if deemed necessary for the care of the patient. All studies should be performed in a manner such that the patient receives the lowest radiation dose possible in order to ascertain the needed information from the examination.

Patient radiation doses are minimized in Nuclear Medicine in several ways. First, administered radio-isotopes are given in doses as low as can be given and still provide a scan of diagnostic quality. Second, the biologic clearance of the radioactive materials should be enhanced as long as it will not interfere with the examination itself. Actually, in most of the studies performed in Nuclear Medicine, increasing biologic clearance actually improves the study quality (in addition to lowering the patient dose). The best example of this is skeletal scintigraphy. Patients undergoing bone scans are asked to increase their intake of fluids and frequently empty their bladders. This increases the rate of clearance of activity from the soft tissues and also improves the target to background ratio (bone to soft tissue).

Safety of the non-occupationally exposed public
In order to minimize the radiation dose to the general public (for example, visitors on patient floors, secretaries, etc) several steps are taken. The first of these is to limit the administration of radioactive materials outside of the nuclear medicine laboratory, a restricted area. Doses are only administered to patients outside of this region when
deemed absolutely necessary. For example, injecting a trauma patient in the ICU for a bone scan when moving them twice would be extremely difficult.

The epilepsy program at DHMC is a special circumstance. Arrangements have been made for epilepsy patients undergoing ictal SPECT to have their injections done within the epilepsy unit. This was necessary due to the lack of predictability of seizure occurrence and the need for video and EEG monitoring of these patients. Special steps that have been taken for this procedure include training of members of the epilepsy program in the safe handling of radio-isotopes and the utilization of a shielded patient room.

**Safety of occupationally exposed workers**
The only individuals permitted to handle and administer radioisotopes are those named on the medical center's radiopharmaceutical license (several of the attending radiologists) and others by acting under their authority (technologists, residents). Before doing so, each person must understand that radioactive isotopes are potentially harmful materials and should be handled with proper technique to ensure maximal shielding and minimize the potential of contamination. This training will be done as part of the nuclear medicine rotation (specifically, each resident will learn the proper technique for the administration of therapeutic dose of iodine-131). It is mandatory for personal radiation monitoring devices (badges) to be worn at all times while in the nuclear medicine work area (actually, in the Department of Radiology). While radioactive materials are being handled, gloves and a ring badge are required as well (along with a white laboratory coat).

**Detection of contamination**
There are mandatory controls to detect radioactive contamination in the nuclear medicine working areas. There is a daily procedure in which a technologist will survey all rooms for contamination utilizing a Geiger Muller counter. Smaller amounts of contamination can be detected with wipe test; these are performed with cotton swabs which are then counted in a well counter. This check is done each week. If contamination is found, is
must be cleaned until the level is once again equal to background. Any area that cannot be cleaned must be shut down until the activity decays to background.