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NUCLEAR MEDICINE

THE PHILIPPINE HEART CENTER EXPERIENCE

by

EMMA L. CANCINO, MD
PNRI

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ABSTRACT

The following is a report of a three (3) months on-the-job training in Nuclear Medicine at the Nuclear Medicine Department of the Philippine Heart Center. The hospital has current generation Nuclear Medicine instruments with data processor and capable of a full range of in vivo and in vitro procedures. Gamma camera is the principal instrument for imaging in Nuclear Medicine used in Philippine Heart Center. Thyroid scanning procedure is being performed with this instruments. Also the cardiovascular procedures, the pulmonary, skeletal, renal and hepatobiliary procedure are being performed with the use of Gamma camera. Special emphasis is on Nuclear Cardiology since the PHC attends primarily to Cardiovascular patients.

The training included academic and practical instructions in Nuclear Medicine. The PHC has a comprehensive three (3) year training program in Nuclear Medicine for physicians who wish to specialize in Nuclear Medicine. The consultants are Nuclear Medicine specialists who were trained abroad, and some are certified by the American Board of Nuclear Medicine.

GAMMA CAMERA

The Gamma Camera is the principal instrument for imaging in Nuclear Medicine. It consists of a large detector, in front of which the patient is positioned. The console contains timers and counters to determine the length of exposure, precise light and gears to reject scattered radiations, and a display from which hard copy images can be recorded on photographic film. It is attached to a computer system in which all data are processed, evaluated and stored for future reference.

At the Philippine Heart Center, a full range of procedures are being performed with this instrument. Thyroid scanning is the most commonly done procedure, which reflects the prevalence of thyroid disease in the country, followed by cardiovascular procedures, then by pulmonary, skeletal, renal and hepatobiliary procedures.

IDEAL CHARACTERISTIC OF A RADIOPHARMACEUTICAL FOR IMAGING

1. Half life should be similar to the length of the test.
2. The radionuclide should emit gamma rays and there should be no charged particle emission.
3. The energy of the gamma rays should be between 50 and 300 kev.
4. The radionuclide should be chemically suitable for incorporating into a pharmaceutical without altering the biological behavior.

5. The radionuclide should be readily available at the hospital site.
6. The pharmaceutical should localize only in the area of interest.
7. The radiopharmaceutical should be simple to prepare.

THYROID GLAND IMAGING

The thyroid gland is one of the largest endocrine organ, normally located in the lower neck and consists of 2 lobes joined by an isthmus that crosses the anterior tract of the 2nd and 3rd tracheal ring. The normal size is 4.0 cm. x 2.0 cm.

Function of the Thyroid Gland

1. Concentration of iodine
2. Synthesis of thyroid hormone
3. Storage of the various hormones and their release to the circulation as required.

Clinical Application of Thyroid Imaging

1. To confirm the presence of a nodule within the thyroid.
2. Identifies the functional characteristics of the nodule.
3. To demonstrate the presence of multiple nodules.

Kinetics of Thyroid Imaging.

Radiopharmaceuticals	Tc 99m pertechnitate	I 123-NaI
Activity administered	1-10 mci	0.5-1 mci
Radiation Dose		
Thyroid	1.5 - 15mGy	7.5 - 75 mGy
Gonads	0.2 - 2 mGy	0.2 - 2 mGy
Stomach	2 - 20 mGy	2.2 - 22 mGy
Whole body	0.1 - 1 mGy	0.3 - 3 mGy
Effective dose equivalent	0.4 - 4 mSv	5 - 50 mSv
Patient preparation	Withdrawal of thyroid medication; Avoidance of food rich in iodine	
Collimator	Pinhole, low energy, high resotion.	
	Started 15 min. after injection	Started 1-2 hrs. after injection

Interpretation of results

1. Normal thyroid gland
   size is 4 x 2 cm. with homogenous symmetrical tracer distribution.

2. Multinodular goiter
   presence of multiple, non functioning cold areas (decreased tracer uptake) interdispersed with focal areas of increased activity as in assymmetrical enlarged thyroid gland.

3. Solitary non functioning thyroid nodule areas that do not concentrate radioisotopes.

4. Hyperthyroidism
   results from the presence of supraphysiological levels of thyroid hormones as a consequence of various diseases.

5. Retrosternal goiter
   substernal aberrant thyroid gland shown as areas of increased uptake.

CARDIOVASCULAR SYSTEM IMAGING

The following cardiovascular procedures are:

- well established with important application
- gives information on cardiac anatomy and physiology
- non invasive
- they complement other non-nuclear modalities
- they are a significant proportion of all Nuclear Medicine procedures done at the Philippine Heart Center

A. Thallium-201 Myocardial Imaging with or without exercise

Indication :

1. To evaluate the patient with suspected coronary artery disease.
2. To evaluate patients who have undergone coronary by-pass surgery
3. To evaluate patients who have had acute infarction
4. To monitor results of coronary artery angioplasties
5. Shows quantification, size and extent of lesions

Procedure :

Patient undergoes a stress test with continuous ECG monitoring. When the patient has reached peak exercise, thallium is injected IV through a previously inserted bore needle and exercise continued for at least 60 seconds.

Adequate stress has occured when patient has reached 85% of maximum predicted heart rate. However, the higher the level of stress, the better the quality of the stress images obtained.

Then 5-10 minutes after the injection, the patient is imaged with a gamma camera, then to be repeated 4 hours later.

Interpretation:

- divided into 3 categories

1. Normal - no abnormality or significant change is seen on the stress and resting images.
2. Ischemia - abnormalities are seen in stress images which disappear on the redistribution ones.
3. Scar - abnormalities are seen in both stress and resting images.

Protocols :

Rest imaging - to determine myocardial viability in acute myocardial infarction.

Stress or exercise imaging - to determine the presence of stress induced ischemia

Delayed imaging - to determine viability of the myocardium.

Kinetics of Myocarial Perfusion Imaging

Radiopharmaceutical	Thallium Chloride
Activity Administerered	1.5-3 mci
Radiation Dose	
Gonads	3-5 mGy
Heart	3-5.5 mGy
Thyroid	12-24 mGy
Colon	14-28 mGy
Effective Dose Equivalent	4.5 - 9 mGy
Patient Preparation	Fasting for 4-6 hrs. - prior to test; cessation of all cardiac medication porticularly Beta Blockers.
Collimator	Low energy, general purpose or high resolution.

THALLIUM

- introduced in Nuclear Medicine in 1975

Physical Properties

1. Cyclotron produced
2. Peak energy emission = 69-83 kev
3. Physical half-life = 73.1 hrs.
4. Contains slight impurities = Pb 203 (0.25%)
   Tl 202 (1.9%)
5. Mercury x-rays near the lower end of resolution scale
6. Mandatory use of high collimator
7. Options to offset limitations

Characteristics of the optimal Radiotracer for Myocardial Perfusion

Present in Thallium

1. No pharmacologic effect at usual dose
2. Regional myocardial distribution proportional to regional blood flow over the physiological range.
3. Rapid blood clearance

Absent in Thallium

4. No myocardial clearance or redistribution
5. Gamma ray energy suitable for imaging
6. Low absorbed radiation dose by the tissues
7. Short effective half-life
8. Ready availability
9. Reasonable cost

Advantages of Thallium over other imaging agents

1. More acceptable for imaging
2. Rapid extraction by the myocardial cells
3. Minimal uptake by the abdominal organs during exercise
4. Adequate for shipment and storage
5. Not altered by cardiac drugs

Disadvantages Of Thallium

1. Low energy emission from the heart
2. Limited use for serial studies
3. Expensive
4. Not readily available

Kinetics of Thallium

1. Organ distribution : heart - 3-5% of injected dose
2. Myocardial extraction efficiency : 85-88%
3. Blood concentration
   1 min. - 10 % of injected dose
   2 hrs. - 1% of injected dose
4. Uptake is linearly related to blood flow
5. Homogenous distribution in the normal left ventricle
6. 80% of peak activity in 1 min.

Myocardial Thallium Distribution Depends On:

1. Delivery
2. Extraction
3. Washout
4. Decay

Factors affecting Uptake

1. Initial blood flow
2. Cellular extraction

Factors affecting Clearance

1. subtances that decrease intravascular Tl concentration
   - glucose, insulin, K solution

Factors affecting Myocardial Tl distribution

1. Initial uptake = regional blood flow
   = extraction efficiency
2. Equilibration process = continuous Tl uptake
   = net myocardial Tl washout

Redistribution Phenomenon

- disparate rate of washout between normal and ischemic myocardium
- continuous Tl uptake
- may begin early after relief of ischemia
- increased Tl concentration in ischemic myocardium
- no evidence of necrosed myocardium
- differentiates scar from ischemia

Kinetics

- excretion is mainly through the kidney in the first 24 hrs.
- biologic half-life is 10 - 2.5 days
- effective half-life is 56 hrs.

B. Myocardial Infarct Avid Imaging

Indication :

1. To evaluate patients with previous Myocardial infarction
2. For evaluation of cardiac performance
3. In cases of intravascular cardiac diseases like budle branch block
4. In cases of sub endocardial infarct
5. To study blood flow through the central circulation
6. To study the morphology of cardiac arteries and the great vessels
7. To delineate the boundaries of intracavitary and intravascular blood pools
8. In cases of radionuclide angiography

Procedure :

The procedure is the same as Thallium myocardial imaging but the radionuclide used is Technetium-99m pyrophosphate.

Interpretation :

Tc-99m labelled pyrophosphate concentrate within severely ischemic and necrotic tissue, thus in films they present as increased tracer uptake on the affected area.

The optimal value of this procedure is between 24-72 hrs. after the onset of the pathology.

Variables affecting Infarct Imaging

1. type and quality of tracer
2. type and quality of instrument
3. size and location of the infarct
4. time of evaluation of the infarct
5. age of the patient
6. experience of the interpreter

Causes of false positive Pyrophosphate studies

1. unstable angina
2. myocardial trauma
3. radiation therapy
4. chemotherapy
5. myocardial tumors
6. valvular calcifications
7. myocarditis, pericarditis
8. ventricular aneurysyms

C. First Pass Radionuclide Angiography

Indication :

To provide information about the anatomy and function of the heart.

a. Qualitative

- shows in dynamic fashion tracer transit through the circulation.
- superior vena caval obstraction
- intracardiac shunt, congenital malformation and pericardial effusion is seen

b. Quantitative

- for processing, display and analysis of abnormality
- for shunt quantitation
- for ventricular function and motility, and del of valvular regurgitation

Procedure :

The same as myocardial infarct avid imaging, but in addition to the usual plates obtained, the tracer transit from the site of injection to the circulation are imaged at specified time intervals.

D. Gated Cardiac Blood Pool Studies

a. Resting Gated Cardiac Blood Pool

Indication :

- to detect ventricular aneurysyms
- for risk stratification in post MI patients
- for monitoring cardiomyopathy
- for follow-up of atrial or mitral regurgitation
- for evaluation of right ventricular functions as in cor pulmonale or COPD

b. Exercise Gated Cardiac Blood Pool

Indication :

- to evaluate myocardial eschemia
- to evaluate wall motion at rest and development of wall motion abnormality during stress
- for evaluation of endocardial function at rest and during stress

E. Biological Metabolic Imaging

These procedures are not yet being done at the Philippine Heart Center as they require more specialized techniques and instruments and specially trained personnel. However they are being done in countries with more advanced technologies.

1. Myocardial Immunoscintigraphy

- done to detect, localize and quantitative myocardial necrosis.
- AgAb are labelled with tracer to permit scintigraphic imaging.
- It is more accurate in infarct sizing than pyrophosphate.
- May image necrosis in myocarditis and evaluate heart transplant rejection.
- Tc-99m labelling and increase demand in the future may bring down cost

2. Thrombus detection and localization using Indium 111m labelled platelets and leukocytes

3. Myocardial Inflammation Scintigraphy in active myocarditis using Ga 67.

4. Myocardial Adrenegic Innervation Scintigraphy for imaging neural tumors using I-123.

5. PET Myocardial

   - positron emitting radionuclide
   - for evaluation of myocardial glucose, fatty acid metabolism and perfusion
   - for research and clinical studies
   - gold standard for myocardial viability

BONE SCAN

Indications:

1. For staging cancer - it demonstrates metastatic disease in bones before the disease is shown radiologically.
2. For diagnostic examination of patients with breast cancer before radical surgery.
3. To determine the extent of metastasis.
4. To evaluate the results of therapy.
5. To investigate any bone lession such as fractures, infection, tumor or healing bone which shows as an increase in activity.
6. To assess the size and extent of primary bone tumor.
7. To confirm the presence of osteomyelitis.
8. To demonstrate the vascularity and avascularity of bone diseases.
9. To investigate bone pains.

Procedure:

Patient is injected with Technetium (Tc-99m) pyrophosphate by intravenous route, then patient is scanned with a gamma camera 4 hrs. post injection to allow the radionuclide to deposit in the bony structures, as this is a bone seeking nuclide. Patient is scanned from head to toes with anterior and posterior views taken. The camera picks up signals from the radionuclide compound administered earlier and images are seen on a TV like screen, transferred in films and are stored in a computer for later studies.

Interpretations:

1. Normal bone scans

- appearance vary with age
- in children, increased uptake are seen in areas of active growth (epiphyses shows very high uptake).

2. Abnormal bone scan

- absent uptake occurs in osteolytic tumors, granulomata and vascular lesions of the bone.
- diminished uptake of bone is seen in severe cardiac failure, in patients with large doses of steroids or vitamin C.
- increased uptake are seen in areas of calcification, infraction of muscle, heart, brain, intestines, spleen.
- benign and malignant neplasms.
- inflammatory conditions as in arthritis.
- infectious processes.
- sites of trauma or injury.

Protocol for Bone Imaging

Radiopharmmaceutical	Tc-99m methylene diphosphate or pyrophospahte
Activity administered	10-20 mCi
Radiation dose	
skeleton	5.6 - 12 mGy
marrow	3.9 - 8.2 mGy
bladder wall	2.4 - 5.1 mGy
gonads	1.4 - 3.0 mGy
whole body	1.7 - 3.8 mGy
Effective dose equivalent	3.2 mSv
Patient preparation	Good hydration. Patient should be encouraged to drink following injection then empty bladder immediately rpior to imaging.

Notes:

- Dental caries and other dental procedures like dental filling also shows increased tracer uptake.
- Likewise, extravasation of the radiotracer in the injection site also shows a very distinct tracer uptake.

KIDNEY SCAN

Indications:

1. To evaluate the presence of infection.
2. To determine the presence of obstruction.
3. To evaluate the extent and nature of trauma in traumatic cases.
4. To evaluate the presence and consequences of high blood pressure.

Procedure:

The patient is injected through intravenous route with Technetium-99m DTPA, then scanned immediately with a gamma camera. Scanning is done from the area of injection at several seconds interval until its deposition in the kidney. Time between administering the compound and taking the scan may vary depending on the coumpound used. Each step is reflected on a TV like screen, then processed in films and are stored in a computer for later study.

Interpretation:

Areas of obstruction are seen as diminished to absent tracer uptake while areas of trauma are seen as marked uptake of the radionuclide.

Radiopharmaceuticals used to assess kidney function

I. Ideal agents used to measure glomerular filtration rate.

1. It must not be bound to plasma and other blood components either reversibly or irreversibly.
2. It must be freely filterable by the glomerular ultrafilter.
3. It must not be actively or passively reabsorbed or secreted by the renal tubular epithelium.
4. It should be chemically pure, stable, and should be metabolically and pharmacologically inert.
5. It must be easily measurable. If radioactive it should give a low radiation dose.
6. The agent must be cleared from the circulation solely by the kidney and not by other organs.

Ideal agents could be any of the following:

- Chromium 51 EDTA
- Iodine 125 - Iothalamate
- Technetium-99m DTPA

II. Ideal agent for measuring renal blood flow

1. It must be metabolically inert.
2. It must be cleared from the circulation by no other organ except the kidneys.
3. Its volume of distribution should exceed plasma volume as little as possible.

Ideal agents for measuring renal blood flow are the following:

- Iodine-131
- Iodine-123   Orthoiodohippurate

III. Ideal Agent for Renal Imaging.

1. It should have an extraction fraction of unity - with irreversible binding of the agent to the tissues of the kidney.
2. It should not be bounded by other tissues or excreted by other organs.

3. Its volume of distribution should be as small as possible to achieve rapid blood clearance and high target.

4. It must have a suitable energy for the available imaging instruments and give a low radiation dose to patients.

5. It should be metabolically and pharmacologically inert, chemically stable and pure.

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards,