Vision: IMC aspires to be a leader in applied medical sciences, health care education and research.
WHAT IS NUCLEAR MEDICINE
RADIOISOTYPE IMAGING?

Mission: IMC is committed to develop highly qualified and competent graduates able to provide leadership and excellence in services to meet the health needs of the nation and the global community through wide range programs, nationally competitive faculty, state-of-the art infrastructure, research applications, and a diverse environment with enriched engagements.
Nuclear radiology is a sub-specialty of radiology in which radioisotopes are introduced into the body for the purpose of imaging, evaluating organ function, or localizing disease or tumors.

Radionuclide imaging is the technique of producing diagnostic images by analyzing the radiation emitted from a patient who has previously been given radioactive medications.
Introduction

- Nuclear medicine **differs** from most other imaging modalities in that the tests mostly show the **Physiological Function**.

- The excretion function of the kidneys, iodine-concentrating ability of the thyroid, blood flow to heart muscle, etc. can be measured.
What is nuclear medicine?

This is a branch of medicine that uses radiation from radioactive tracers to provide information about the function of specific organs.
What is nuclear medicine?

In some cases, radioactivity can be used to treat certain conditions such as an overactive thyroid.
Radiation is a type of energy, which exists in our environment in many forms and comes from both natural and man-made sources.
Answering your questions

What is radiation?

**Light** that allows us to see and the warmth we get from the sun or from nature are natural forms of radiation.
What is radiation?

Examples of man-made radiation include the microwave radiation that is used for cooking and radio waves for communication over long distances.
Ionizing radiation comes from both natural and man-made sources. It comes from outer space, the sun, the earth, the air, our food and drink and from the buildings we live in.
Answering your questions

What is radiation?

This is the **natural background** radiation to which everyone is exposed. Each of us receives a small dose of naturally occurring radiation on an annual basis.
What is radiation?

Nuclear medicine studies use ionizing radiation, as do x-ray studies.
Answering your questions

What is radiation?

Nuclear medicine is extremely safe because the radioactive tracers or radiopharmaceuticals commonly used are quickly eliminated from the body through its natural functions.
### What is radiation?

In addition, the tracers used rapidly lose their radioactivity. In most cases, the dose of radiation necessary for a scan is very small.
Answering your questions

What is radiation?

For example, a patient having a lung scan is exposed to the same dose of radiation they would receive from eight return air flights between Sydney and London.
Answering your questions

What is a half-life?

Nuclear medicines used for diagnosis or treatment generally have short half-lives. A half-life is the time it takes for the level of radioactivity to drop to half the starting level.
Answering your questions

What is a half-life?

Nuclear medicines typically have a half-life of several hours or days. This means they rapidly lose their radioactivity level within the predetermined half-life.
Answering your questions

<table>
<thead>
<tr>
<th>Where are radiopharmaceuticals produced?</th>
</tr>
</thead>
<tbody>
<tr>
<td>In fact, without the ability to produce radiopharmaceuticals, we would have to import them from as far away as Europe, Canada and South Africa.</td>
</tr>
</tbody>
</table>
Where are radiopharmaceuticals produced?

Radiopharmaceuticals are manufactured by using a cyclotron and its nuclear research reactor.
Answering your questions

Where are radiopharmaceuticals produced?

It is necessary to have both the research reactor and the cyclotron as each produces different types of radiopharmaceuticals.
### Answering your questions

<table>
<thead>
<tr>
<th>Where are radiopharmaceuticals produced?</th>
</tr>
</thead>
<tbody>
<tr>
<td>The manufacturing process is regulated by strict quality-control requirements.</td>
</tr>
</tbody>
</table>
Answering your questions

Where are radiopharmaceuticals produced?

The radiopharmaceuticals are supplied to nuclear medicine center. Every year thousands of people are diagnosed and treated at these centers.
**Answering your questions**

<table>
<thead>
<tr>
<th>Where are radiopharmaceuticals produced?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without access to this vital technology, many patients would be facing a reduced quality of medical care.</td>
</tr>
</tbody>
</table>
### Answering your questions

<table>
<thead>
<tr>
<th>What is the difference between radiopharmaceuticals made in a cyclotron and those made in a nuclear reactor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>The nucleus of an atom contains two types of particles – neutrons and protons.</td>
</tr>
</tbody>
</table>
## Answering your questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
</table>
| What is the difference between radiopharmaceuticals made in a cyclotron and those made in a nuclear reactor? | Non-radioactive atoms have a ‘stable ratio’ of neutrons and protons in the nucleus, while radioactive atoms have an ‘unstable ratio’.

What is the difference between radiopharmaceuticals made in a cyclotron and those made in a nuclear reactor?

Radioactive atoms are made by adding either extra neutrons or extra protons.
What is the difference between radiopharmaceuticals made in a cyclotron and those made in a nuclear reactor?

Atoms with extra neutrons in the nucleus are **neutron-rich**; they are produced in a **nuclear reactor**; this is the great majority of medically useful radiopharmaceuticals.
What is the difference between radiopharmaceuticals made in a cyclotron and those made in a nuclear reactor?

Atoms with extra protons in the nucleus are proton-rich and are produced in a particle accelerator such as a cyclotron – they complement those manufactured in nuclear reactors.
What is the difference between radiopharmaceuticals made in a cyclotron and those made in a nuclear reactor?

| Neutron-rich and proton-rich radioisotopes decay by different means and thus have different radioactive properties and different medical uses. |
What is the difference between radiopharmaceuticals made in a cyclotron and those made in a nuclear reactor?

Both types of radioisotopes are needed to service all of nuclear medicine needs. **Over 80 per cent** of the radioisotopes used in medical procedures, including the most commonly used radiopharmaceutical technetium-99, can only be produced economically in a nuclear research reactor.
Answering your questions

When is a nuclear medicine scan needed?

There is about a one in two chance of a patient needing a nuclear medicine scan during his or her lifetime.
When is a nuclear medicine scan needed?

Scans using radiopharmaceuticals can diagnose numerous conditions. Scans of the heart, thyroid, lungs and kidney are common.
When is a nuclear medicine scan needed?

However, by far the majority of scans involve the skeleton. These are usually carried out to diagnose infection, tumor spread, and fractures or sports injuries.
Answering your questions

<table>
<thead>
<tr>
<th>Should I prepare for a scan?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some scans may require special preparation. As with other tests, if you are pregnant or if there is any possibility that you may be pregnant or if you are breastfeeding, you must tell your physician.</td>
</tr>
</tbody>
</table>
**Answering your questions**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should I prepare for a scan?</td>
<td>It is important that you read all the material given to you prior to your appointment.</td>
</tr>
</tbody>
</table>
When you undergo a scan, a radiopharmaceutical will be given, either by injection into a vein, by mouth or through a breathing device. The radiopharmaceutical will concentrate in the particular part of your body under investigation.
Answering your questions

What can I expect when I have a scan?

Sometimes you may have to wait for a few hours or even a day or two after the radiopharmaceutical has been administered for the scan to be done.
Answering your questions

<table>
<thead>
<tr>
<th>What can I expect when I have a scan?</th>
</tr>
</thead>
<tbody>
<tr>
<td>This is because it may take a while for the radiopharmaceutical to lodge in the part of your body to be examined.</td>
</tr>
</tbody>
</table>
What can I expect when I have a scan?

The radiopharmaceutical continuously gives off invisible radiation, known as gamma rays. The images are stored digitally on computer for reporting doctors who will be able to tell if the part of your body being tested is functioning normally.
**Answering your questions**

<table>
<thead>
<tr>
<th>Are there different types of scans?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, there is gamma camera imaging and positron emission tomography (PET) imaging.</td>
</tr>
</tbody>
</table>
Are there different types of scans?

| Gamma imaging operates in two different modes, **PLANAR** imaging and single photon emission computed tomography (**SPECT**) imaging. |
Are there different types of scans?

If your doctor refers you for a nuclear medicine scan, one or more of the following methods may be used:
Are there different types of scans?

**PLANAR imaging:** PLANAR is the most common of the three methods. It involves the injection into the body of a small amount of a chemical substance tagged with a radioactive tracer.
Answering your questions

Are there different types of scans?

Depending on the chemical substance used, the radiopharmaceutical concentrates in the part of the body being investigated, for example the skeleton, lungs, heart or liver, and gives off gamma rays.
Answering your questions

Are there different types of scans?

A gamma camera produces a two-dimensional image of the radioactivity occurring in that organ.
Are there different types of scans?

SPECT imaging:- SPECT is also widely used and the process of injecting a radioactive tracer is the same as the PLANAR technique.
Answering your questions

Are there different types of scans?

Instead of being stationary, the gamma camera moves around the body providing a series of images. This takes about 20-30 minutes.
Answering your questions

Are there different types of scans?

SPECT and PLANAR imaging are highly convenient technologies as they use radiopharmaceuticals, which can be easily distributed, stored and mixed ready for use at nuclear medicine clinics and hospitals.
Are there different types of scans?

PET imaging:- PET is a very similar technique to SPECT but uses different radiopharmaceuticals. The radiopharmaceuticals required for PET have very short half-lives and are produced by a cyclotron.
Answering your questions

Are there different types of scans?

The most common radiopharmaceutical used is radioactive sugar. PET studies require you to lie quietly for up to one hour after the injection so that the radiopharmaceutical localizes correctly rather than going to your muscles.
### Answering your questions

<table>
<thead>
<tr>
<th>Will I have to stay in hospital?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients having a diagnostic scan will often be asked to stay in the nuclear medicine department for a few hours, although in some cases patients are asked to return for a number of visits or to stay in hospital for a short period.</td>
</tr>
<tr>
<td>Question</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Will I have to stay in hospital?</td>
</tr>
</tbody>
</table>
Will I have to stay in hospital?

If you do need to stay for certain types of therapy, then you will usually only be in hospital for two or three days. This is not because of any risk to your health but because doctors want to ensure that radioactive materials are dealt with safely when they are excreted from your body.
What does nuclear medicine treatment involve?

By far the widest application of nuclear medicine is for diagnosis. However, there are a number of occasions when radioactive materials are used to treat certain conditions, particularly cancer. This is known as therapy.
<table>
<thead>
<tr>
<th>What does nuclear medicine treatment involve?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear medicine therapy usually involves taking radiopharmaceuticals orally (either in capsule or liquid form) and the most common conditions treated in this way are overactive thyroids and thyroid cancer.</td>
</tr>
</tbody>
</table>
### What does nuclear medicine treatment involve?

Radiopharmaceuticals are also injected into the body, usually the joints, to treat certain types of arthritis. Newer treatments involve the intravenous injection of radiopharmaceuticals for the relief of pain from tumors that have spread to bone.
What does nuclear medicine treatment involve?

Many patients are treated with radiopharmaceuticals that have a medical effect on their bodies. For most, one dose is all that is required.
Are there any side effects?

Side effects are extremely rare for diagnostic scans. When radiation or radiopharmaceuticals are used in therapy, there are sometimes minor side effects. These will be explained to you by the nuclear medicine staff together with measures to reduce or avoid the symptoms.
Answering your questions

Who carries out nuclear medicine procedures?

If your doctor recommends you have a scan or nuclear medicine treatment, you will be placed in the care of a team of specially trained professionals.
Answering your questions

Who carries out nuclear medicine procedures?

Physicians, technologists, pharmacists and nurses will ensure that you receive a high level of care and that your doctor is provided with accurate reports on your condition.
What happens after a scan or therapy?

The specially trained physicians will report on the scan’s appearance and send the results to your doctor to evaluate, together with those of any other tests you may have had. In the majority of cases, you will be able to continue your daily activities as usual.
What are the benefits of nuclear medicine?

Nuclear medicine enables doctors to produce a quick and accurate diagnosis for a wide range of conditions and diseases at any age. In turn, this allows the appropriate treatment to begin as early as possible, which gives a far greater chance of being fully effective.
Answering your questions

What are the benefits of nuclear medicine?

In addition, the tests are painless and most scans expose patients to only a minimum amount of radiation. It is a very accurate way to examine whether some tissues are functioning properly.
Answering your questions

What are the benefits of nuclear medicine?

Therapy using nuclear medicine is an effective, safe and relatively inexpensive way of controlling and in some cases, eliminating certain conditions such as an overactive thyroid, thyroid cancer and certain types of arthritis.
What are the benefits of nuclear medicine?

Nuclear medicine is a vital part of healthcare as it gives many people the opportunity of continuing to live full and healthy lives.
Nuclear Medicine
(Radioisotope imaging, Radionuclide Scanning or Scintigraphy)
Basic Principle

- In diagnosis, radioactive substances are administered to patients and the radiation emitted is measured.
- The majority of these diagnostic tests involve the formation of an image using a Gamma Camera.
After the radioactive material is administered.

The patient lies very still on a table while a special camera detects gamma radiation. Which is transmitted to computer.

The physician studies the computerized images to assess how well an organ is functioning.
Essential Requirements

- The Radiopharmaceutical.
- The Radiation Detection System.
- The Analyzing System.
- The Display & Recording System.
Radiopharmaceuticals or Radiotracers

- They are **radioactive compounds**.
- When these agents are **injected I.V.** into the patients, they are **up taken by the target tissues**, **accumulate in them**, then detected and imaged by external detectors, and imaging systems.
Radiopharmaceuticals

Natural

Artificial
Radioisotopes and Radioactivity

- **Radioisotopes** are isotopes with unstable nuclei which undergo radioactive disintegration.

- **Isotopes Definition:**
  Isotopes are different forms of a single element. They are atoms with the same number of protons, but differing numbers of neutrons.

- This disintegration is often accompanied by the emission of radioactive particles or radiation.
The important emissions include:

- Alpha particles
- Beta- (electron) and beta+ (positron) particles
- Gamma radiation.
Summary of The Main Properties & Characteristics of Radioactive Emissions
<table>
<thead>
<tr>
<th>Property</th>
<th>Alpha particles</th>
<th>(^\beta)Beta particles</th>
<th>Gamma rays</th>
<th>(^\beta)Beta particles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nature</strong></td>
<td>Particulate (mass, volume &amp; charge)</td>
<td>Particulate (Electrons)</td>
<td>Electromagnetic radiation (Identical to x-rays)</td>
<td>Particulate (Positron)</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>Large</td>
<td>Small</td>
<td>Nil</td>
<td>Interacts very rapidly with a negative electron to produce 2 gamma annihilation rays</td>
</tr>
<tr>
<td><strong>Charge</strong></td>
<td>Positive</td>
<td>Negative</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>Slow</td>
<td>Fast</td>
<td>Very fast</td>
<td></td>
</tr>
<tr>
<td>Property</td>
<td>Alpha particles</td>
<td>-Beta particles</td>
<td>Gamma rays</td>
<td>+Beta particles</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------</td>
<td>-----------------</td>
<td>------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Range in tissue</td>
<td>1-2 mm</td>
<td>1-2 cm</td>
<td>As with x-rays</td>
<td></td>
</tr>
<tr>
<td>Damage caused</td>
<td>Extensive ionization</td>
<td>Ionization</td>
<td>Ionization (similar to x-rays)</td>
<td></td>
</tr>
<tr>
<td>Use in nuclear medicine</td>
<td>Banned</td>
<td>Very limited</td>
<td>Main emission used</td>
<td>PET</td>
</tr>
</tbody>
</table>
Radioisotope Imaging

- Radioisotope imaging relies upon altering the patient by making the tissues radioactive.
- The patient becomes the source of ionizing radiation.
Radioisotope Imaging (cont.)

This allows Examination of:

- Function
- Structure

of the target tissue.

- Under both static and dynamic conditions.
Radioisotope Imaging (cont.)

- A radioactive substance is produced in a machine called a **Cyclotron**.
- It attached (tagged), to a natural body compound that have an affinity for particular tissues.
Radioisotope Imaging

Cyclotron

Radioactive substance

Substance that has an affinity for a particular tissue

attached (tagged)

Injected I.V. to the patient
Radioisotope Imaging (cont.)

- After I.V. injection, the radioactive material localizes in the target tissues.

- Their radiation emissions are then detected by a gamma camera.
A gamma camera is a device used to image gamma radiation emitting radioisotopes, a technique known as scintigraphy.
Gamma Camera

Nuclear Energy (Inside the radioactive nucleus) → Gamma Electromagnetic Energy (The gamma ray has been emitted from the patient) → Light Electromagnetic Energy (The image crystal produces flashes of light) → Electrical Energy (To display the image)
- Sodium iodide with thallium NaI(Tl)
- The main function of crystal is convert gamma ray to photons of visible light process called scintillation.
- Amount of light proportional to deposited energy.
Today, technetium $^{99m}$Tc is the most widely used imaging isotope in nuclear medicine!!
Why?

- It produces a single 141 Kev (kilo electron volts) gamma emission which is ideal for imaging purposes.
- It has a short half-life of 6 ½ hours which ensures minimal radiation dose.
- It is easily produced, as and when required, on site.
It is easily attached to a variety of different substances that are concentrated in different organs, e.g.:

- Tc + MPD (Methylene Diphosphonate) in bone
- Tc + red blood cells in blood
- Tc + sulphur colloid in the liver and spleen

It can be used on its own, in its ionic form since this is taken up selectively by the thyroid and salivary glands.
Tc-99m

Radioactive decay

Gamma ray/photon emission (140KeV)

Gamma camera

Light pulse

Voltage Signal

Image

ATOM

ATOM
Main Indications for Isotope Imaging

- Tumor staging: Site and size of bone metastases.
- Investigation of Salivary Gland Function.
- Evaluation of Bone Grafts.
- Assessment of Condylar Hyperplasia (bone disease).
- Investigation of the Thyroid Gland.
- Brain Scans.
Increase Uptake In Left Condyle

Increase uptake in left condyle

*Condylar hyperplasia vs. chondrosarcoma*
Bone scan of a 30-year old female with a history of fibrous dysplasia.

Scan shows uptake in right mandible and right temporal bone.
A technetium 99m-bisphosphonate; 
Bone scan of a patient with "polyostotic Paget's" disease.
Advantages Over Conventional Radiography

- Target tissue **function** is examined.
- **All similar target tissues** can be examined during one examination. *e.g.* the whole skeleton can be imaged during one bone scan.
- **Computer analysis** and enhancement of results are available.
Disadvantages

- Poor image resolution.
- Minimal information on target tissue anatomy.
- Difficult to localize exact anatomical site of source of emissions.
- Relatively high radiation dose to the whole body.
- Images are not usually disease-specific.
- Some examination take several hours.
- Facilities are not widely available.
Gamma rays are emitted from the patient and detected by a gamma camera **rotating** around the patient.

The distribution of radioactivity is displayed as a **cross-sectional image** enabling the exact site of the source of the emissions to be determined.
SPECT bone scanning offers both enhanced:

- Image contrast.
- Resolution.
- More accurate localization of active disease as it provides 3D information.

Allowing the examiner to visualize in sagittal, transaxial, and coronal slices, structures that would overlap on planar views.
Positron Emission Tomography (PET)
PET is a noninvasive, diagnostic imaging technique for measuring the metabolic activity of cells in the human body.

- It was developed in the mid 1970s and it was the first scanning method to give functional information about the brain.
- Some radioactive isotopes decay by the emission of a positively charged electron (positron) from the nucleus.
- This positron usually travels a very short distance (1-2 mm) before colliding with a free electron.
In this reaction, the mass of the two particles is annihilated with the emission of two gamma rays of high energy (511 keV) at almost exactly 180° to each other.

These emissions, can then be detected by opposite radiation detectors which are arranged in a ring around the patient.

The exact site of origin of each signal is recorded and a cross-sectional slice is displayed as a PET scan.
Positron Emission Tomography (PET)
Positron Emission Tomography - PET

Radionuclide with excess protons → Decay → Positrons → Positron + electron collision → Annihilation reaction generates two 511-keV gamma photons → PET detector ring for localization & imaging
What are some of the uses for PET

- Patients with conditions affecting the brain
- Heart
- Certain types of Cancer
- Alzheimer’s disease
- Some neurological disorders
The Major Advantages of PET

- A **functional** imaging technique having a **unique detection method** so it can be used to study:
  - Tissue perfusion.
  - Cell receptors.
  - Head & neck cancer.
Advantages of PET (Cont.)

- A variety of new radioisotopes can be used with PET including:
  - Carbon (11C)
  - Oxygen (15O)

- These radioisotopes can be used on their own or joined with biologically important compounds (e.g. glucose, amino acids, and ammonia).
Advantages of PET (Cont.)

- Investigate disease at a molecular level, even in the absence of anatomical abnormalities on CT or MRI.
- It is possible to superimpose a PET scan on a CT scan, by a technique known as Co-localization, to determine a lesion’s exact anatomical position (To detect structure and function).
- i.e., Higher diagnostic accuracy than PET or CT alone.
Image showing malignant breast mass that was not revealed by conventional imaging techniques such as CT, MRI, and mammogram.
Floor is open for Questions and Discussion

Thank you