Principles of Medical Imaging

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Objectives

- **Learner should be able to**:

  i. identify various types of energy sources and image properties in medical imaging

  ii. distinguish between the principles and imaging chain arrangements of the common modalities

Physical basis of Medical Imaging

- Imaging modalities include:

1. X-ray imaging
2. Ultrasound
3. Radionuclide Imaging
4. Magnetic Resonance Imaging
5. Dual Modality

Different forms of energy

- X-ray imaging employs short wavelength, highly penetrating electromagnetic radiation (**x-rays**)

- Ultrasound imaging employs very high frequency sound a mechanical form of energy (**ultrasound**)

- Radionuclide imaging uses a form of electromagnetic radiation similar to x-rays but originating from radioactive materials (**gamma-rays**)

- MRI employs magnetism and long wavelength electromagnetic radiation (**radiowaves**)

1. X-ray imaging

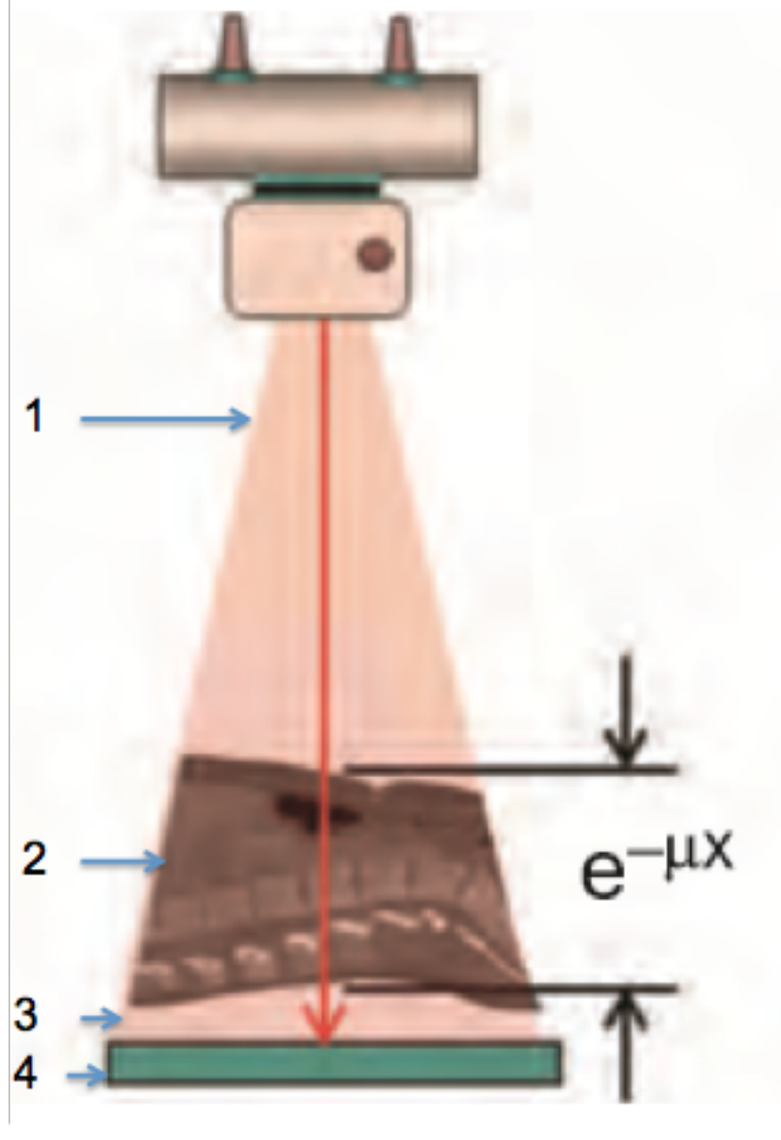
- Based on studying the pattern of x-rays transmitted through the body
- Different tissues attenuate x-rays to different extents depending on their physical characteristics
- Pattern of attenuation is contained in the invisible latent image transmitted through the body
- Latent image is made visible using an image receptor

1. Uniform x-ray beam incident upon subject

2. Differential attenuation of x-ray beam in different structures within subject factors: atomic number, density, thickness

3. Latent image represents pattern of attenuation; it is non-uniform, visible

4. Image receptor makes latent image visible



Bushberg et al 2012, pg 208

- Different application areas for x-ray imaging includes:

conventional radiography, fluoroscopy (screening), conventional tomography, computed tomography, mammography, dental x-ray

- Ability to distinguish between tissue structures varies in these different areas of x-ray imaging

- The use of artificial contrast agents may enhance tissue differentiation

2. Ultrasound Imaging

- Beam of ultrasound produced in transducer is directed at subject (frequencies 1- 20 MHz)
- Reflections of the ultrasound occurs at tissue boundaries based on the changes of physical characteristics of the boundaries
- Returning echoes are detected by the transducer and measured
- The magnitude of reflected echoes and the locations of the reflecting boundaries are mapped to generate the ultrasound image

Bushberg et al 2012, pg 528

3. Radionuclide Imaging (RI)

- A radioactive nuclide which emits gamma radiation is used to tag/label a pharmaceutical agent that selectively concentrates in a particular organ or tissue

- The combination of radionuclide and pharmaceutical agent is known as a radiopharmaceutical (radpham)

- When a radpham is administered internally to the patient, the highly penetrating gamma rays emitted by the radionuclide leave the concentrating organ and can be externally detected

- The spatial distribution of radiopharmaceutical is mapped to produce the image. This image is based on the location and concentration of emitted gamma radiation

- The information from radionuclide images relate to the chemical and physiologic status of the target organ

Bushberg et al 2012, pg 707

- Planar radionuclide imaging

- Single photon emission computed tomography (SPECT)

- Positron emission tomography (PET)

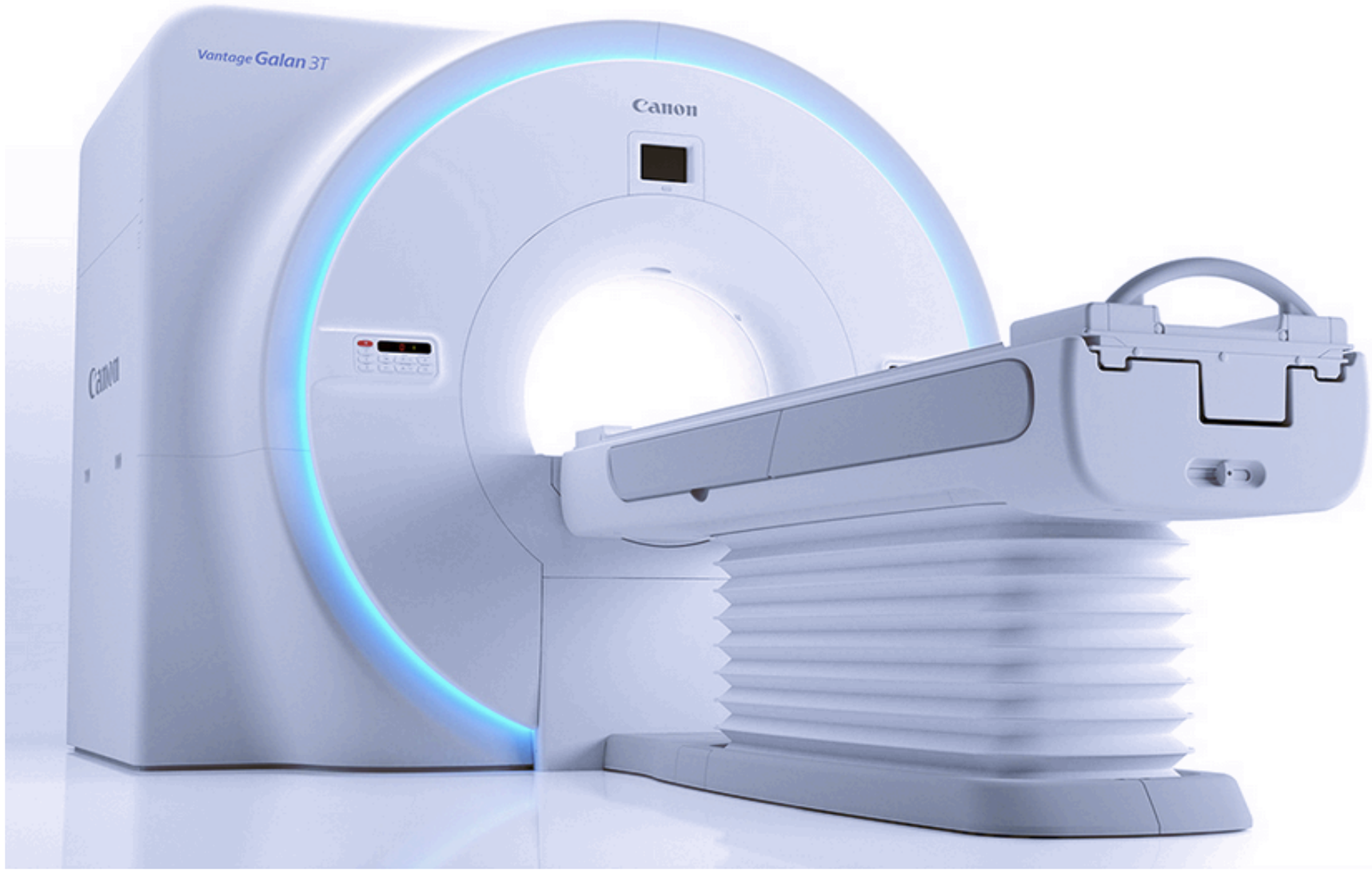
4. Magnetic Resonance Imaging (MRI)

- Magnetism latent in the nuclei of certain atoms is stimulated by exposure to strong magnetic fields and radio-frequency (RF) pulses

- During de-excitation, the stimulated nuclei emit RF signals

- The concentration of nuclei (strength of emitted RF signal) and rates at which the de-excitation takes place (relaxation times) are studied to generate images

- The most important MRI-friendly nucleus is ^{1}H in body water
- The MRI provides high contrast information based on the ^{1}H concentration and magnetic properties of the tissues interrogated in the environments in which they exist



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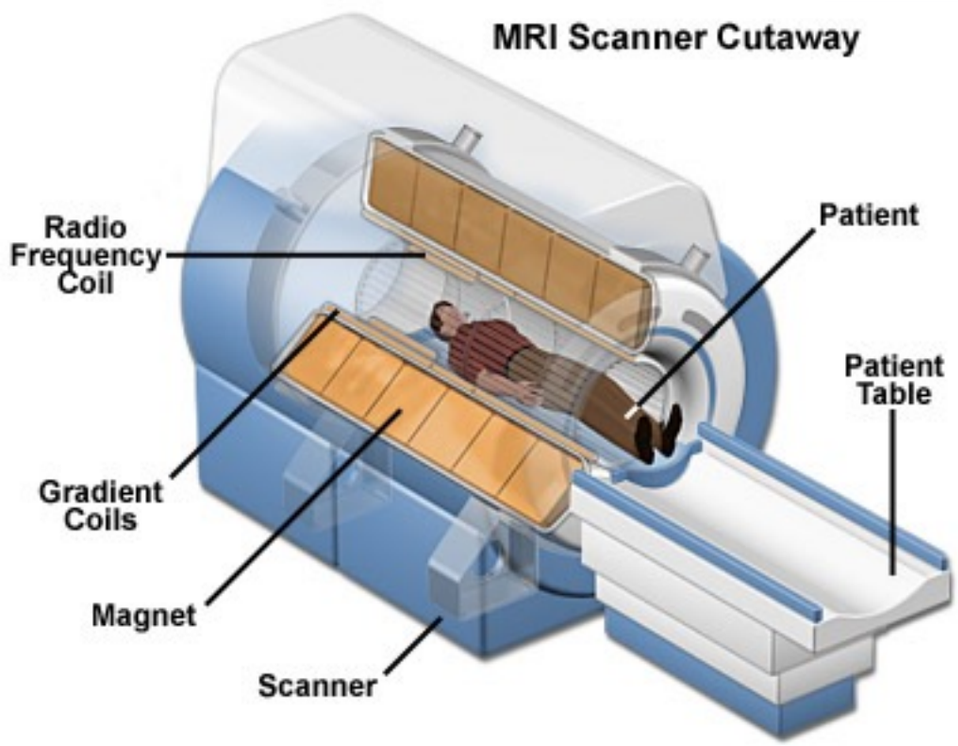

Figure showing MRI scanner

5. Dual Modality Imaging

- Each imaging modality has its own strength and limitations

RI has high sensitivity for lesions but poor anatomical details while MRI or CT have excellent anatomical detail

- Hence, a fusion of two modalities e.g. PET/ CT, SPECT/ CT

Unique features of imaging modalities

- The different imaging modalities are associated with unique features in respect of:
    - the nature of information it provides (e.g. physical, chemical, physiologic, paramagnetic)
    - sensitivity (e.g. early detection)
    - ability to depict detail (e.g. spatial resolution, contrast)
    - ability to depict dynamic change (e.g. uptake and excretion rate)
    - safety of forms of energy used (ionizing vs non-ionizing radiation)

References

1. The Essential Physics of Medical Imaging 3rd Edition by Bushberg *et al* , 2012

2. Christensen's Introduction to the Physics of Diagnostic Radiology by Curry *et al,* 1990