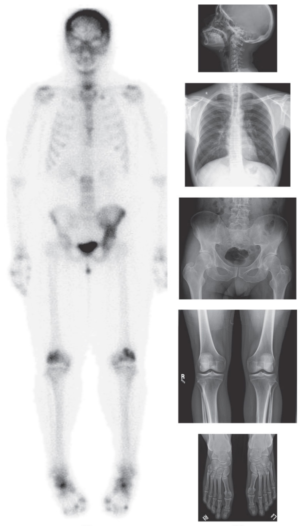
(a) Emission image vs. (b) transmission images

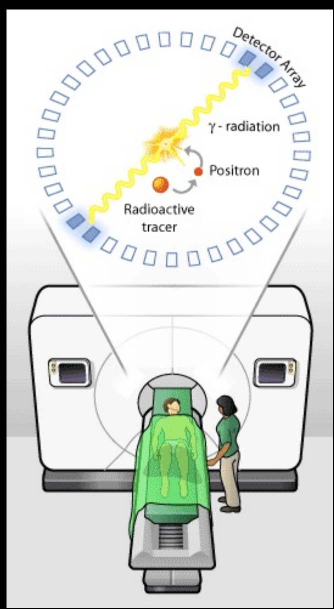


(a) (b)

1

Nuclear Medicine

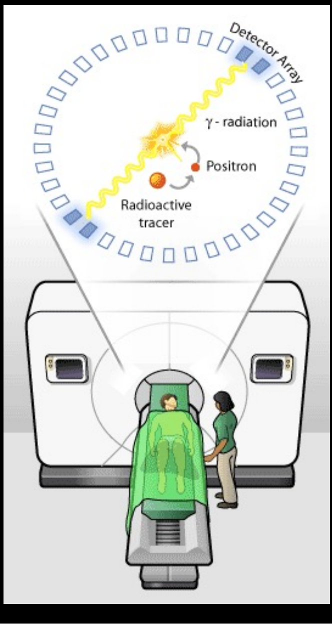
- X-ray & CT: “transmission” of photons through the body to form images
- Nuclear Medicine: “emission” of photons from within the body



2

Nuclear Medicine

- A radionuclide is injected into the blood stream
- Goes to "hyperactive" locations e.g., cancer or healing cells
- Emitted Gamma rays are detected for imaging
- Very low resolution, but high sensitivity



3

Nuclear Medicine

- Biological behavior of a substance's biodistribution in the body
- Label each molecule of the substance with a radioactive atom
- "Functional" imaging modalities: body's physiological and biochemical functioning
  - Example 1:
    - Metabolic activity of the bone → activity during healing process

      vs.
    - Structural information→ bone fracture
  - Example 2:
    - Myocardial perfusion → disribution of blood flow in the heart muscle

      vs.
    - Coronary angiography → anatomy of the coronary arteries

4

Radiotracers

- Radioactive tracer (radiotracer) could be
  - Injected into a peripheral arm vein of the patient
  - Inhaled
  - Ingested
- 100s of different radiotracers, each asses the function of a different physiologic process
- Radiotracers decays to form gamma rays, which are then detected
- Radioactive decay: Aton rearranges its protons and neutrons to end up with lower inherent energy → energy released as ionizing radiation

5

Radiotracers

- Radiotracer determines which physiological or biochemical function is being imaged
- Compare with X-ray or CT: image depends on parameters or instruments, but the information is the same (anatomy)
- Radiotracer is selectively taken up by an organ or lesion

7

Most Commonly Used Radiotracer

- Te99m (Technicium) : Most commonly used radiotracer
  - Emits 140 keV gamma rays
  - 6 hr half life
- Uptake region appears dark in the image
- **Problem:**
  - Radiation continues even after imaging
  - Poor images, resolution around 1 cm, noisy
- Advantages: Shows function directly

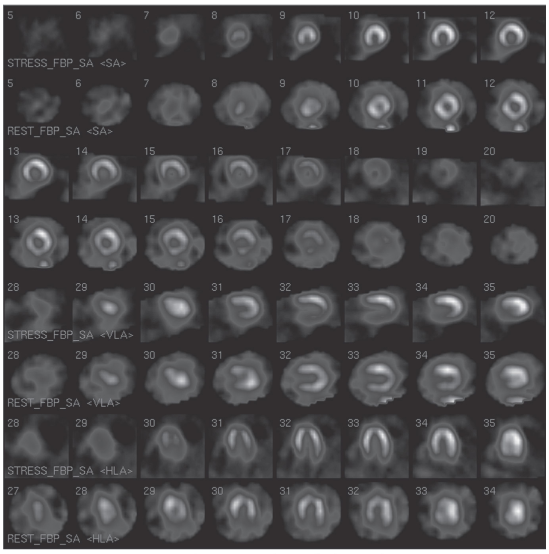
8

Nuclear Medicine

- Three different modalities
  - Scintigraphy (projection format - 2D)
  - Single-photon emission computed tomography (SPECT)
  - Positron emission tomography (PET)
- Scintigraphy and SPECT: radionuclide decays to form gamma rays, which are then detected
- PET: radionuclide decays to produce a positron, which then immediately annihilates with an electron to produce two gamma rays that fly off in opposite directions

9

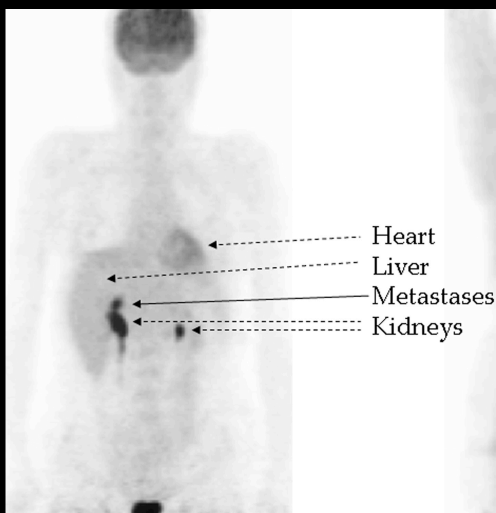
Myocardial perfusion imaging via SPECT



10

Positron Emission Tomography

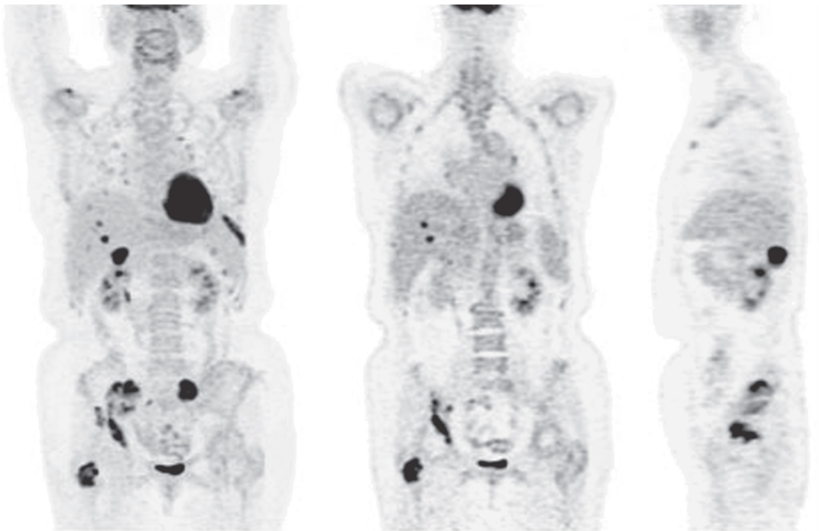
- Resolution is not good, but very sensitive to cancer



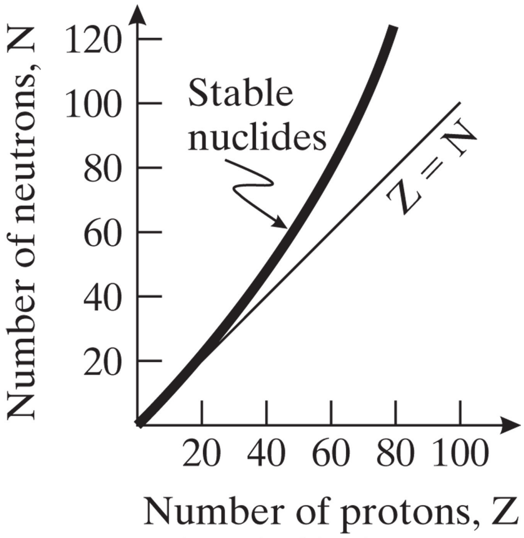
11

Whole-body FDG-PET

FDG: Fluorodeoxyglucose (^{18}F) → sugar
cancer cells uptake more sugar → cancer diagnoses



Stable elements having proton/neutron pairings that lie on the *line of stability*



Radiotracers

- There are 1500 known radionuclides
- ~200 can be purchased commercially

- We want "clean" gamma ray emitters
  - without particle radiation that cause additional dosage but does not contribute to the image

- IMPORTANT NOTE: We do NOT want attenuation of the radiation (unlike x-ray or CT). We want to detect them all!!

14

Radiotracers

- We want to detect location of emitters
  - Energy should be high, so μ is small
  - Energy should not be too high, because we want rays to interact with the detector
  - Typical 70-511 keV gamma rays

- Half life is important: ~minutes to hours
  - If too short, cannot image
  - If too long, creating the image takes too long
  - Some radiotracers need to be made on-site in generators or cyclotrons

15

TABLE 7.1

Common Radionuclides in Nuclear Medicine

Gamma Emitters **(Used in Scintigraphy and SPECT)**

Z	Nuclide	Half-life	Photon Energy (keV)
24	Chromium-51	28 d	320
31	Gallium-67	79.2 h	92, 184, 296
34	Selenium-75	120 d	265
38	Strontium-87m	2.8 h	388
43	Technetium-99m	6 h	140
49	Indium-111	2.8 d	173, 247
	Indium-113m	1.73 h	393
53	Iodine-123	13.3 h	159
	Iodine-125	60 d	35, 27
	Iodine-131	8.04 d	364
54	Xenon-133	5.3 d	81
80	Mercury-197	2.7 d	77
81	Thallium-201	73 h	135, 167

16

TABLE 7.1

Common Radionuclides in Nuclear Medicine

Positron Emitters **(Used in PET)**

Z	Nuclide	Half-life	Positron Energy (keV)
6	Carbon-11	20.3 min	326
7	Nitrogen-13	10.0 min	432
8	Oxygen-15	2.1 min	696
9	Fluorine-18	110 min	202
29	Copper-64	12.7 h	656
31	Gallium-68	68 min	1,900
33	Arsenic-72	26 h	3,340
35	Bromine-76	16.1 h	3,600
37	Rubidium-82	1.3 min	3,150
53	Iodine-122	3.5 min	3,100

Source: Wolbarst, 1993.

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17

Popular Radiotracers

- Iodine-123, Iodine-131: administer orally, measure in thyroid a day later to assess thyroid function
- Technetium-99m: filtered by kidneys, assess renal function
- Gaseous O2, with Oxygen-15: measures blood flow, assess oxygen metabolism
- FDG with Fluorine-18: sugar (glucose), uptaken by brain or highly active cells in the body (e.g., cancer)

18