Radionuclides in Medical Imaging

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Outline

- Definitions
- History and development
- Radionuclide applications & techniques in imaging
- Conclusion
Definition #1: Radionuclide

- An unstable **nucleus** of an atom which emits some form of radiation (alpha, beta, gamma) as it drops to a lower-energy state.
Definition #2: β and γ radiation

- β radiation occurs when an electron (or positron, in the case of β+ decay) and a neutrino particle are ejected from the nucleus.

- γ radiation occurs when a *high-energy* photon is ejected from the nucleus.

- Exposure results in cancer significantly more often than in superpowers.
Definition #3 : Nuclear Medicine

- A branch of medicine that involves the use of radioactive isotopes of certain atoms in the diagnosis and treatment of a variety of diseases

- Medical imaging uses the radionuclides in the diagnosis of the disease

- An example of treatment using nuclear medicine is the use of radiation therapy to battle cancer
History and Development

- Enrico Fermi’s 1935 discovery that stable elements can be made radioactive allowed this field to be pioneered.

- The increased neutron count resulted in an unstable nucleus which would emit alpha, beta, or gamma radiation.

- Another key for this field was the invention of the cyclotron by Ernest Orlando Lawrence in 1930.
History and Development

- John Lawrence proposed using radioisotopes to treat cancer

- First human treatment: 1937

- First **successful** human treatment: 1939
  - Phosphorus 32 was used to treat polycythemia vera

- First **major successful** human treatment: 1946
  - Iodine-131 stopped thyroid cancer growth and could be used to diagnose certain thyroid diseases as well as generate an image of the thyroid
History and Development

- By 1970’s: images of most organs can be taken
  - Includes thyroid, spleen, liver, and location of brain tumors

- By 1980’s: heart conditions can be diagnosed using high-precision cameras

- Today: Over 100 procedures involving radioisotopes are practiced in the diagnoses and treatment of many different diseases and conditions
Positron Emission Tomography (PET)

- Positron emitting isotope is introduced to body and accumulates in target organ.
- Positron interacts with electron and produces two opposing gamma rays, captured by a camera.
- Monitored in terms of “hot” and “cold” spots.
- Often coupled to Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) scans.
- Can produce 2D and 3D images.
Positron Emission Tomography (PET)
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Positron Emission Tomography (PET)

- Diagnose and track progression of complex diseases
  - Dementia
  - Movement disorders
  - Cancer
  - Epilepsy
  - Drug abuse
  - Grave’s disease
  - Coronary artery disease
  - Metabolic disorders
Positron Emission Tomography (PET)

- Scans cost 2,000 – 3,000$
- Requires a cyclotron or special generator to produce tracer
- Tracers require frequent recalibration
- Requires very careful planning wrt scheduling patients
Single Photon Emission Computed Tomography (SPECT)

- Costs 400$/scan
- Low resolution
- Yield “true” 3D image
- Measures biological activity
- Exploits gamma decay
- Detects single photons
Single Photon Emission Computed Tomography (SPECT)

- Often used in neurological diagnoses
  - Stroke/TIA
  - Recurrent tumor vs. radiation necrosis
  - Brain death
  - Epilepsy
  - Dementias

- Also used in functional cardiac imaging as well as bone imaging
Radioactive Iodine Uptake Test (RAIO)

- Yields information about the size, shape, position and function of the thyroid and/or parathyroid

- Can be SPECT or PET

- Up to three scans taken, scan time under 30 minutes
Lung Ventilation and Perfusion (VQ) Scan

- Ventilation: air intake
- Perfusion: blood flow
- Tests take about an hour
- Detection of obstructions, shunts, embolisms, COPD, pneumonia, etc.
- Uses SPECT
Lacrimal Scan

- Tear duct scan
- Measures flow of tears in eyes
- 1-2 drops of radioactive tracer added to each eye
- SPECT detection
- Scan time 30-45 minutes

FIGURE 5: Lacrimal scan one year postoperatively demonstrates that lacrimal flow function is perfectly normal with tracer flowing freely into the nose on the operated and non-operated sides.
Conclusion

- Nuclear medicine scanning is more sensitive than other techniques, and offers valuable functional information.

- Nuclear medicine scanning can be used to diagnose and monitor the progression of a large variety of diseases.

- Both direct and indirect gamma detection are important, as are both 2D and 3D scans.

- Nuclear medicine scanning can be both time consuming and expensive.
Questions?

An example of what gamma rays will NOT do to you.