Uses of VARSKIN in a Medical Hospital Environment

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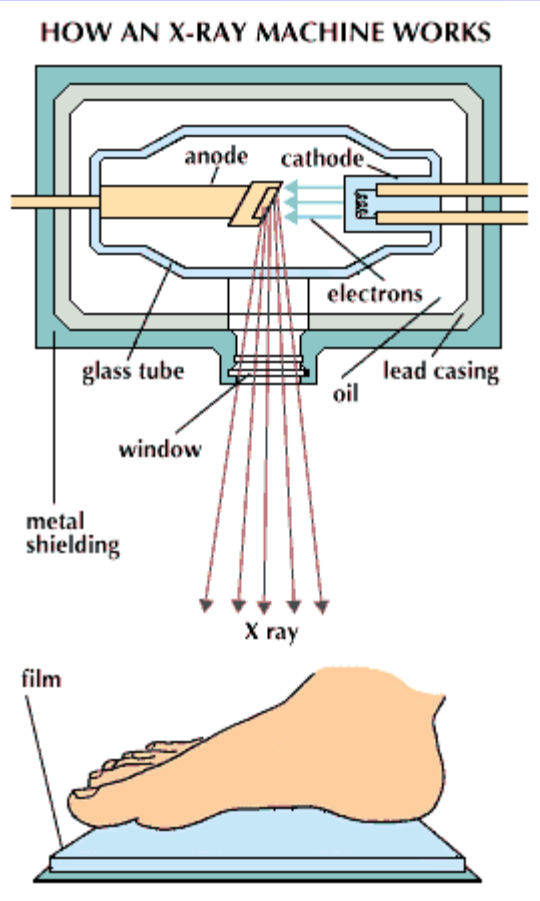
and
RAdiation Dose Assessment Resource

Nuclear Medicine: Basic Principles

- Medical imaging – external sources of radiation



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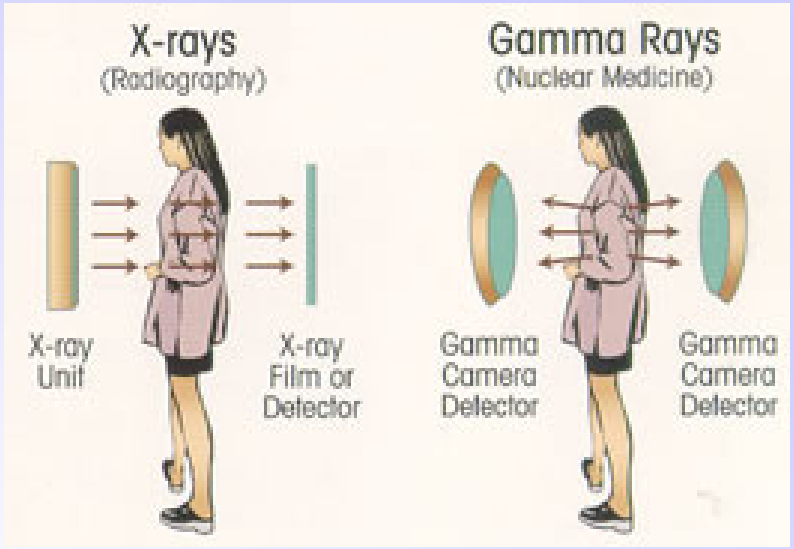
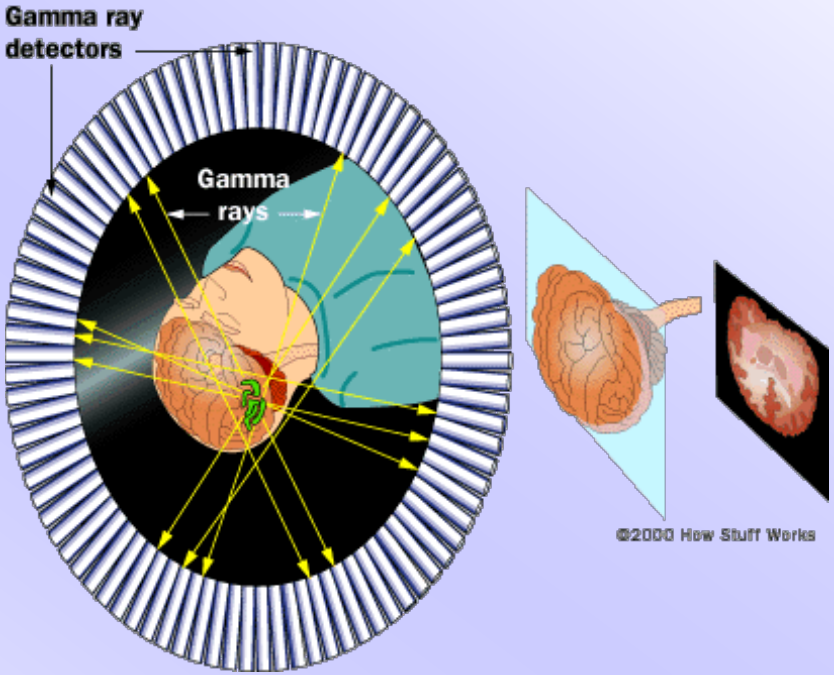
Nuclear Medicine: Basic Principles

- Nuclear medicine – internal sources of radiation



http://www.doemedicalsciences.org/pubs/sc0033/radio.shtml



http://health.howstuffworks.com/nuclear-medicine1.htm

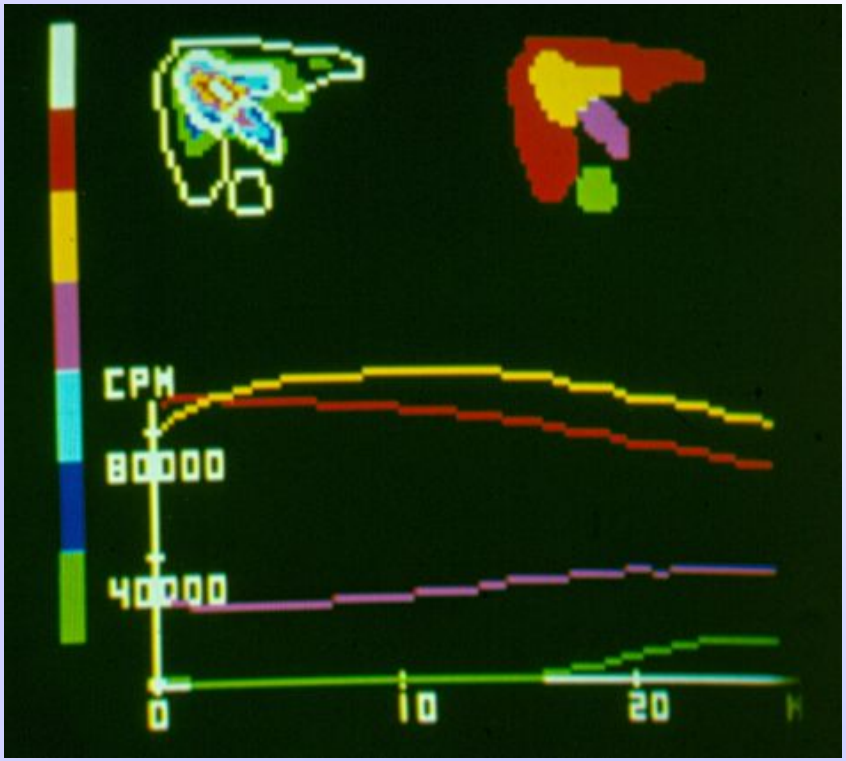
Nuclear Medicine: Basic Principles

- Images take some time to acquire – subjects must remain as motionless as possible.

http://www.dbh.nhs.uk/Library/MediaServicesImages/Nuclear%20Medicine.jpg

Nuclear Medicine: Basic Principles

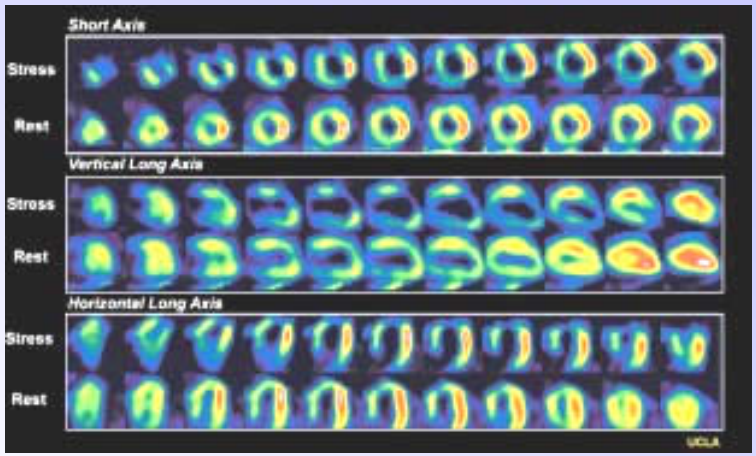
- The key distinction between nuclear medicine and almost all other imaging modalities – images may indicate *dynamic* information – function, not just structure.
- One may draw Regions of Interest (ROIs) on images and the counts in the ROIs can be tracked over time.

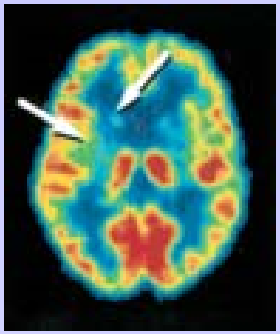


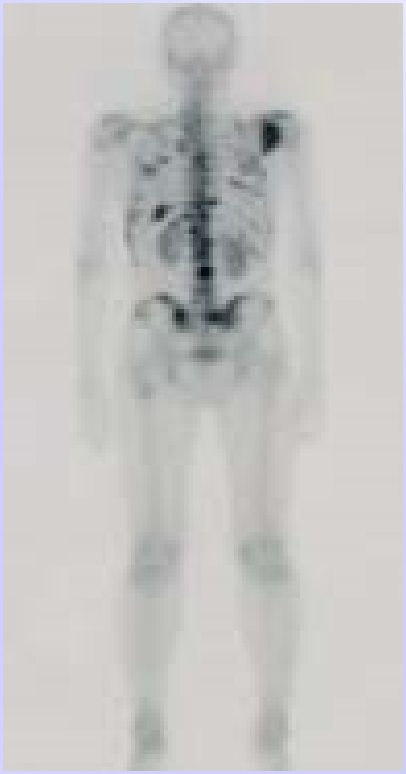
http://www.inf.u-szeged.hu/ipcg/projects/segams-80.html

Nuclear Medicine: Basic Principles

- Radiopharmaceuticals are designed to concentrate in and thus image most any region of the body.



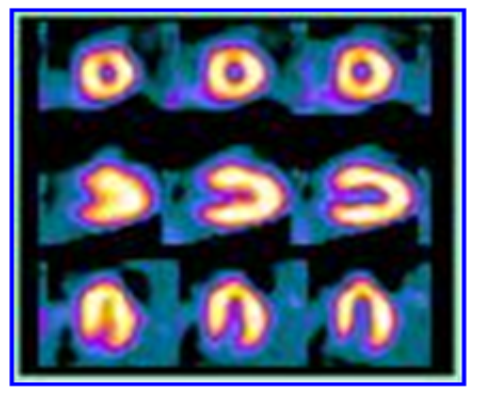




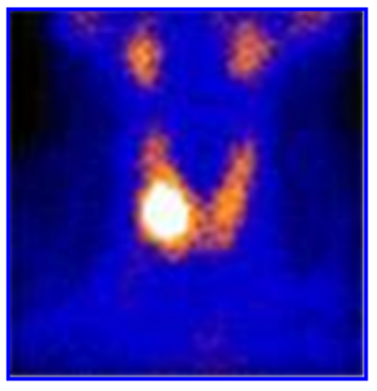
http://www.doemedicalsciences.org/pubs/sc0033/radio.shtml

Nuclear Medicine

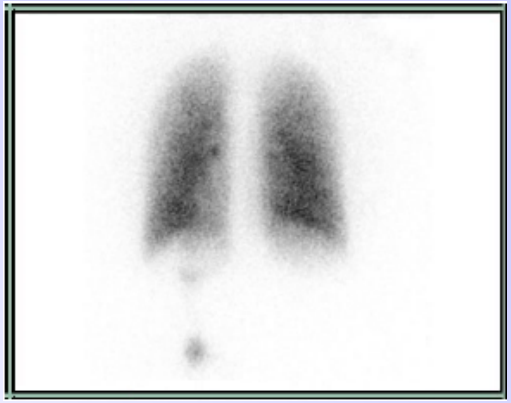
Radiopharmaceutical administration – Intentional internal contamination!



Injection



Ingestion



Inhalation

Medical Uses of Radionuclides

- Use of radiopharmaceuticals for:
  - Planar and SPECT (Single Photon Emission Computed Tomography) imaging for diagnosis
  - PET (Positron Emission Tomography) Imaging for oncology
  - Treatment of thyroid disorders
  - Radioimmuodiagnosis and therapy
  - Liver cancer
  - Bone/marrow cancers
  - Neuroendocrine tumors

PET Imaging

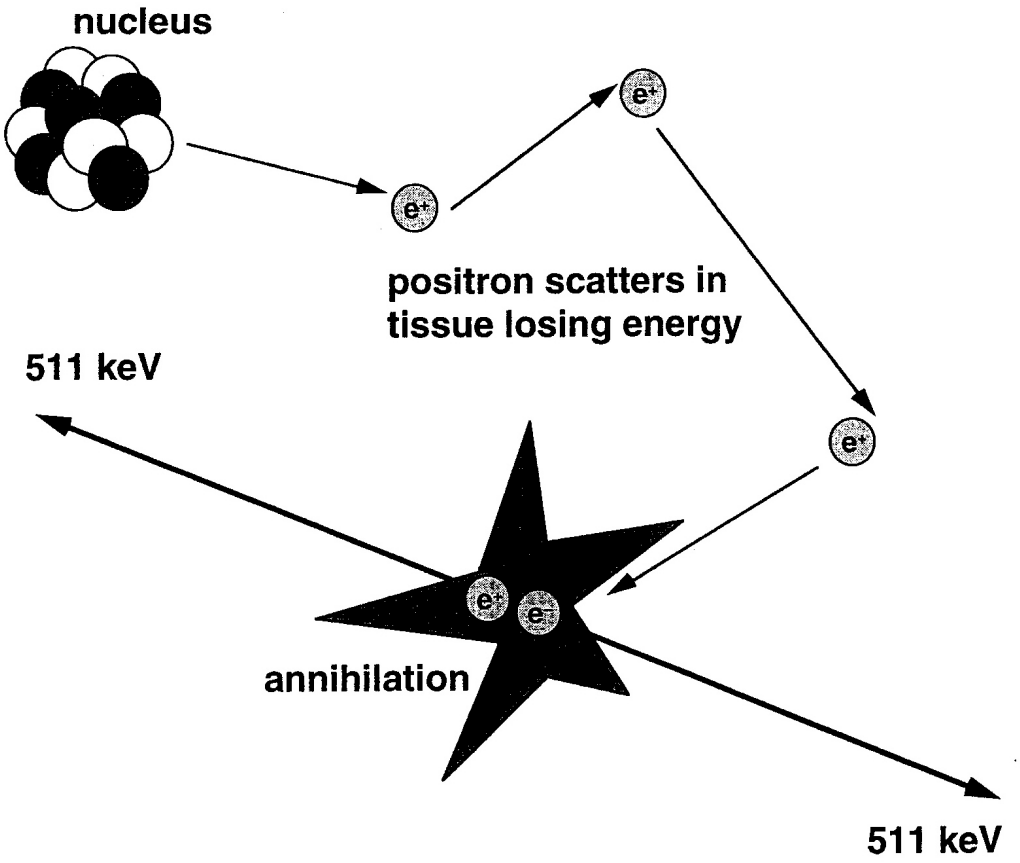
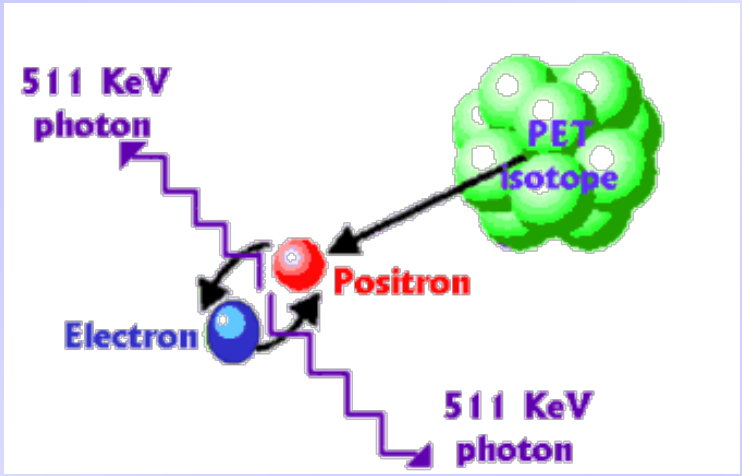
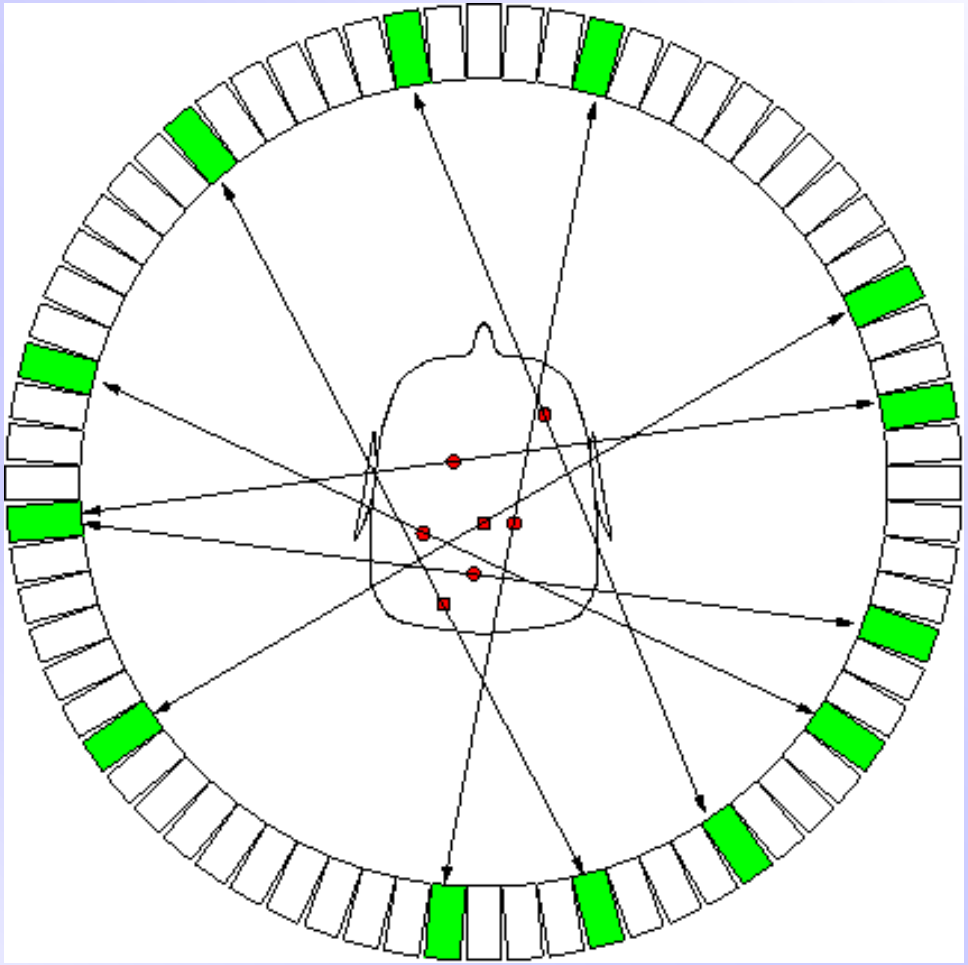


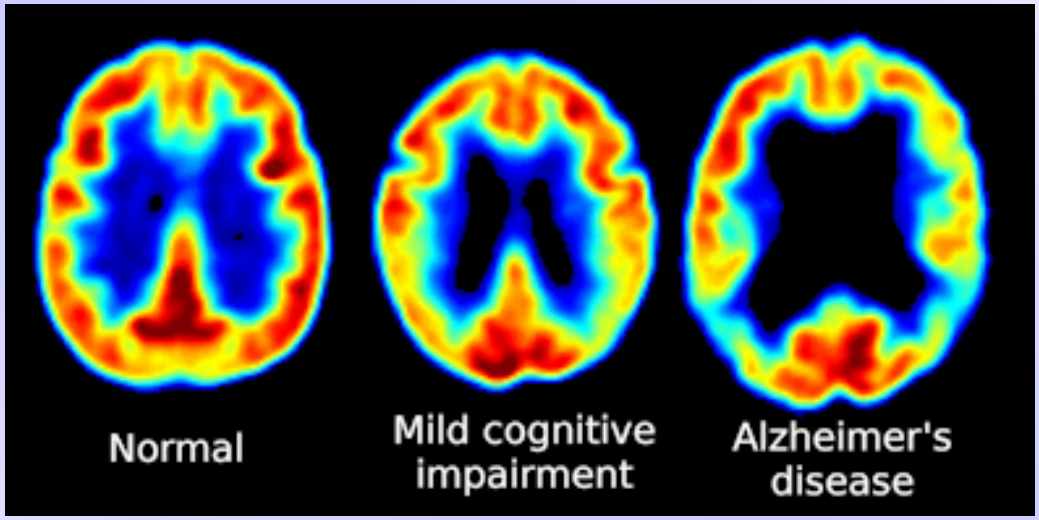
FIGURE 5.3. Proton-rich isotopes can decay by means of positron emission. The positron rapidly loses kinetic energy, scattering off atomic electrons. It slows sufficiently to combine with an electron, and the two particles are annihilated. Their mass is converted into energy in the form of two 511-keV γ-rays, which are emitted back to back.

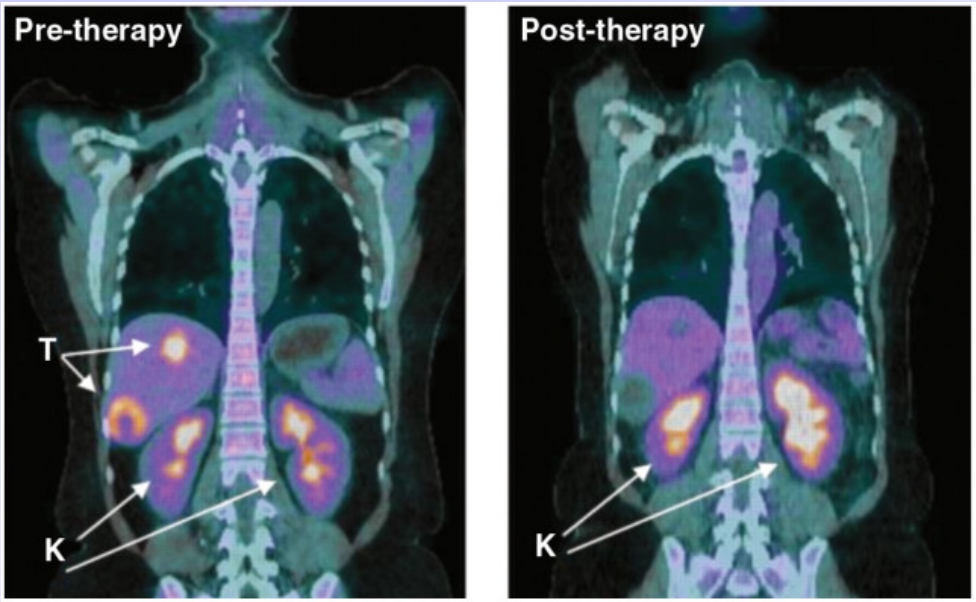

511 KeV
photon
PET
isotope
Positron
Electron
511 KeV
photon



Mechanisms

- F-18 FDG (fluorodeoxyglucose) – Malignant cells develop significant alterations in metabolism in transforming from normal cells.
- Increased glycolysis (main metabolic process under anaerobic conditions)
  - More glucose transporter molecules at tumor cell surfaces
  - Activation of genes coded for synthesis of glucose transporters
  - Enhanced activity of enzymes controlling the glycolytic pathway





T – tumor in liver (pre- and post-therapy)
K – kidney (does not contain tumor but concentrates FDG)

Source: *Science* 324, 1029 (2009).

^{18}FDG – Case Study

- Individual drawing liquid ^{18}F into a syringe from a vial containing ~1300 MBq (35 mCi) of ^{18}F within a hood.
- Pressure in the vial caused the filter to break and spray the contents of the vial.
- Individual immediately surveyed himself to identify all areas of contamination. Contamination was present on the hood, the floor, his gloves, his lab coat, his head, his wrists, and his shoes.
- Individual removed all contaminated PPE and clothing and performed two extensive decontaminations of his head, hands, and wrists.

^{18}FDG – Case Study

- Very rough activity estimates based on survey meter readings, short exposure time assumed, VARSKIN estimates:
  - 0.34 mGy left wrist
  - 0.17 mGy cheek
  - 1.2 mGy right ear
  - 0.34 mGy top of head

Zr-89 PET tracers

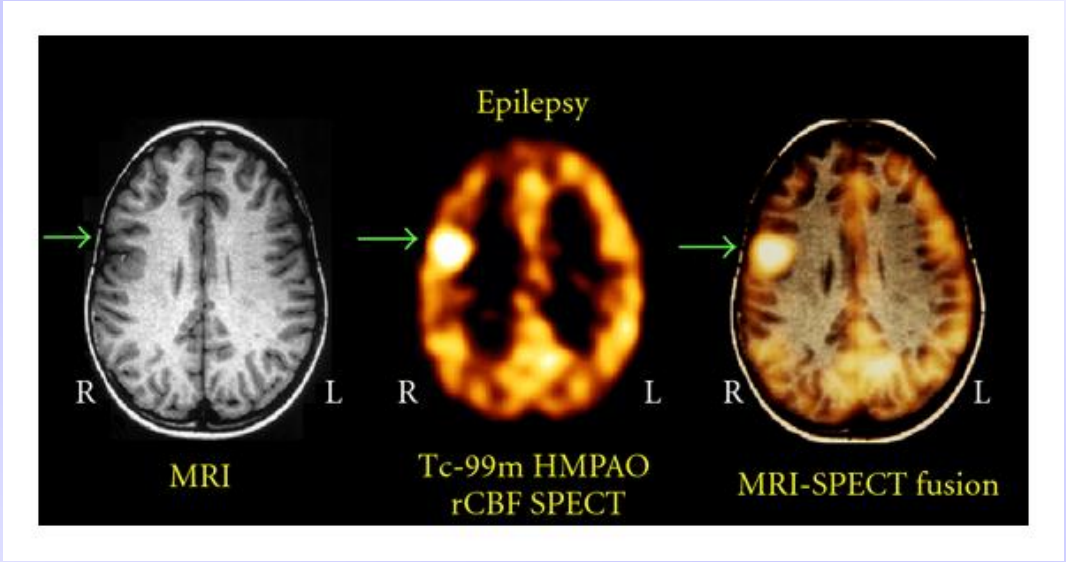
- ^{89}Zr-based PET imaging has been investigated for a wide variety of cancer-related targets, which include:
  - Human epidermal growth factor receptor 2,
  - Epidermal growth factor receptor,
  - Prostate-specific membrane antigen, splice variant v6 of CD44,
  - Vascular endothelial growth factor, carbonic anhydrase IX, insulin-like growth factor 1 receptor (and others).

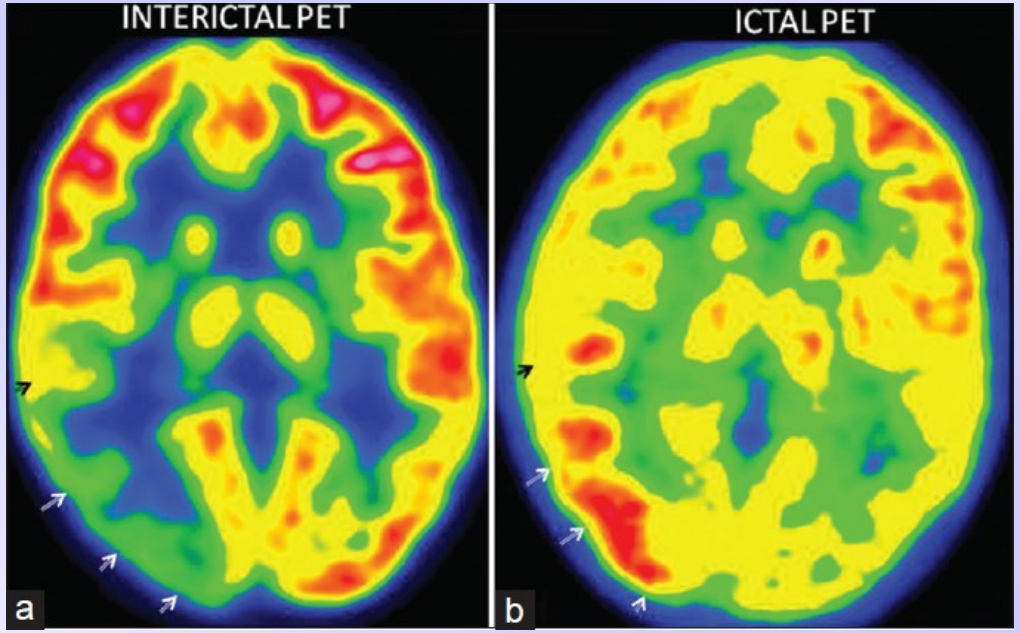
Zr-89 Case Study

- Researcher performing a labeling experiment using ~150 MBq (4 mCi) of ^{89}Zr within a hood. During the labeling researcher contaminated his right arm with the contents of the vial.
- Removed all contaminated PPE and clothing and performed two extensive decontaminations of his hands and wrists.
- Activity on skin and clothing evaluated with survey meter, decontamination procedures implemented.
- Assuming that a majority of the initial activity was removed immediately and that the residual activity remained on the skin until it decayed completely, the VARSKIN dose was about 10 mGy to the right wrist.

Tc-99m Ictal SPECT Studies

- Brain perfusion studies with compounds like ^{99m}TcECD (ethyl cysteinate dimer), ^{99m}Tc HMPAO (hexamethylpropyleneamine oxime) produce SPECT tomograms depict the distribution of blood flow and perfusion to the various structures of the brain:
  - Diagnosis of Alzheimer's disease.
  - Localization of seizure foci.
  - Evaluation of carotid blood flow prior to surgical occlusion.
  - Diagnosis of brain death.
  - Evaluation of brain injury.


Epilepsy
R
L
R
L
R
L
MRI
Tc-99m HMPAO
rCBF SPECT
MRI-SPECT fusion


INTERICTAL PET
ICTAL PET
a
b

Tc-99m Ictal SPECT Case Study

- Ictal EEG tech was removing the syringe with a diagnostic dose of ^{99m}Tc from the patient's i.v. line when a small amount of the ^{99m}Tc splattered out of the connection, slightly contaminating her forehead and neck as well as two spots on the floor.
- Almost all of the ^{99m}Tc remained in the syringe.
- Activity on skin and clothing evaluated with survey meter, decontamination procedures implemented.

Tc-99m Ictal SPECT Case Study

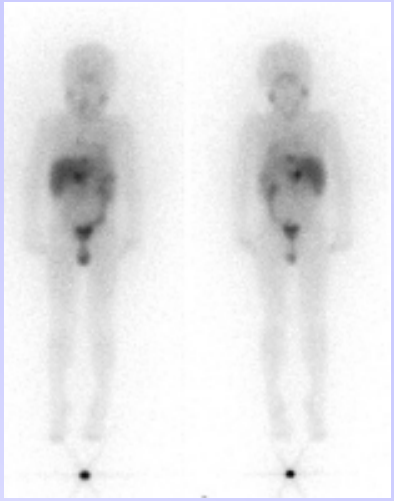
- Assuming:
  - The initial activity was in place for an hour (the approximate times noted in the investigation indicate it was somewhat less than an hour),
  - The residual activity remained on the tech until it decayed completely (the tech was getting ready to leave for the day and was instructed to shower upon returning home; the shower would in all probability have removed a significant fraction of this activity),
  - The VARSKIN estimated dose to the tech's skin was 0.30 mGy to the forehead and 0.10 mGy to the neck.

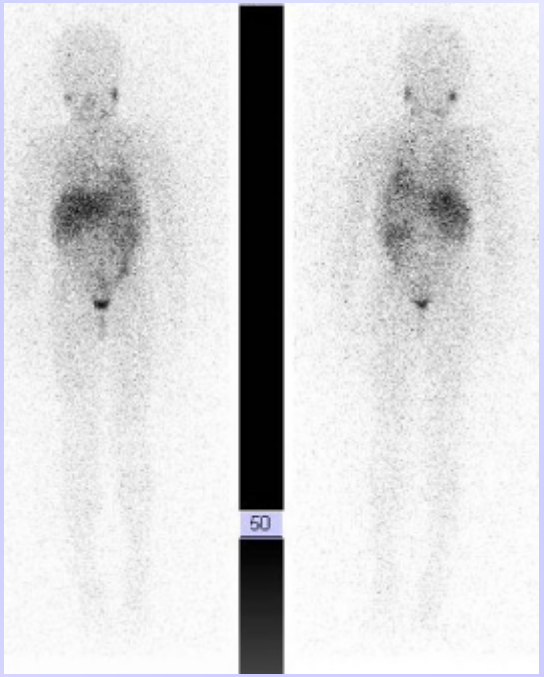
I-131 mIBG

- ^{131}I-metaiodobenzylguanidine (mIBG) - management of neuroendocrine tumors (NET), the most frequent malignant extracranial tumor in childhood.
- The incidence of clinically relevant diseases is about 10 per million under the age of 15 years.

I-131 mIBG

- Treatment options depend mainly on the initial stage. For patients with stage I or II and favorable biological tumor characterization, surgical resection alone is curative in almost all cases.
- In stage III, surgery and chemotherapy are often the therapeutic approaches.
- In stage IV, multimodal therapy includes chemotherapy, surgery, local radiation, and high-dose therapy with autologous hematopoietic stem cell rescue (ASCR).



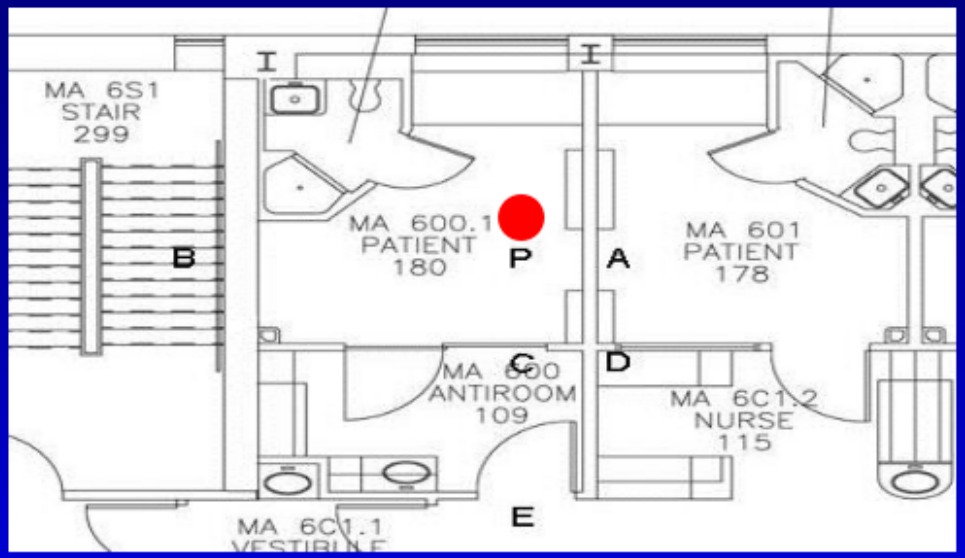


Child diagnosed with stage IV neuroblastoma at age 4, treated with chemotherapy, but still positive with ^{18}FDG scanning. After two ^{131}I mIBG treatments, external radiation and interferon, stable four years later.

I-131 mIBG

- Administration of 450-1850 MBq/kg.
- Infuse slowly, mIBG itself may introduce blood pressure changes.
- Administer fluids to reduce radiation dose to kidneys and bladder.
- Significant exposures possible to staff, family members.
- Shielding requirements significant.

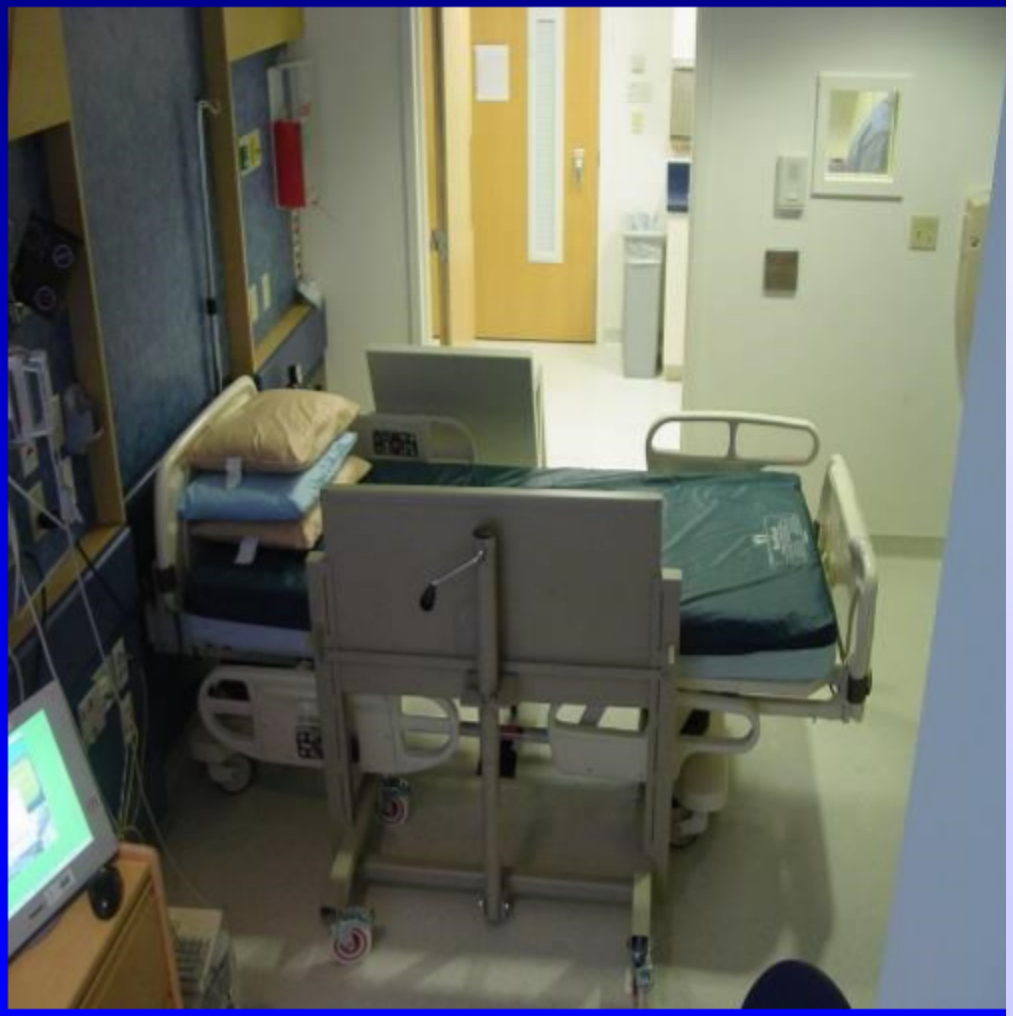
BCH Example Recommended Shielding



Dose Point	Design Lead Thickness (inches)
Wall A	1.0 (1”)
Wall B*	0.25 (1/4”)
Wall C	0.5 (1/2”)
Ceiling Above*	0.625 (5/8”)
Floor Below*	0.125 (1/8”)

Patient Room Preparation

- Large mobile lead shields surround the bed.
- A lead box at the foot of the bed shields the urine collection bag.
- Most surfaces of the room (floors, bedrails, etc) will be covered with plastic.
- Equipment will also be covered with plastic.
- Several large containers are used for waste.



I-131 mIBG – Case Study 1

- Routine linen change, urine disposal, and bath for a ^{131}I-mIBG patient a family care giver (FCG) entered the treatment room placing absorbent PPE on her bare feet.
- As the FCG exited the treatment room, she informed rad safety staff that her PPE came off her right foot and she had stepped on the contaminated plastic covering the treatment room.
- Surveys conducted with survey meter and decontamination with washcloth.
- Assuming that a majority of the initial activity was removed immediately and that the residual activity remained until it decayed completely, the VARSKIN estimated was 3.87 mGy to the arch of the foot.

I-131 mIBG – Case Study 2

- Catheter leak caused urine spill onto a patient's legs and floor. FCG cleaned patient immediately.
- Rad safety staff performed radiation surveys and decontamination.
- Assuming that a majority of the initial activity was removed immediately and that the residual activity remained until it decayed completely, the VARSKIN estimated was 0.59 mGy to the right leg and 0.15 mGy to the left leg.

I-131 mIBG – Case Study 3

- ^{131}I-MIBG activity infused: 37 GBq (1,000 mCi)
- Patient catheterized, leak discovered 1 day later.
- Fraction of administered activity about 0.026, or 26 mCi.
- Contaminated skin surface area about 100 cm^2.
- Approximately 4 hour exposure time.

Varskin 4

Date: 4/24/2013 Time: 3:25:08 PM

MIBG-SkinDose

Disk Source Geometry

Source Diameter: 1.13E+01 cm

Source Area: 1.00E+02 cm^2

Irradiation Time: 4.00E+00 hr

Irradiation Area: 1.00E+01 cm^2

Skin density thickness: 7.00E+00 mg/cm^2

Air Gap Thickness: 0.00E+00 mm

Nuclide: I-131

Half Life: 192.96 h

Average Beta Energy: 0.1537745 MeV

X-99 Distance: 0.081704997 cm

Source Strength: 2.00E+02 MBq

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	2.83E+03 mGy/h	1.13E+04 mGy	1.12E+04 mGy
Photon	2.92E+01 mGy/h	1.17E+02 mGy	1.16E+02 mGy
Total	2.86E+03 mGy/h	1.14E+04 mGy	1.14E+04 mGy

Conclusions

- A variety of radionuclides are used in nuclear medicine applications, in both diagnostic and therapeutic realms.
- In the production and use of the associated radiopharmaceuticals, contamination incidents will occur from time to time.
- Doses from diagnostic cases are low, but may be considerable in therapy cases.
- VARSKIN is an invaluable tool for evaluation of these incidents.