PET IMAGING

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Topics Covered:

- Introduction and Principles
- Instrumentation
- Image Acquisition
- Radiopharmaceuticals
- Patient Prep and Procedures
- Image Findings and Indications

Introduction

- Ability to image on molecular level.
- Image resolution is best in Nuclear Medicine.
- Early detection of cancer and other diseases.
- Many new promising imaging indications in the future.
- Physiology AND Anatomy imaged with new PET/CT machines.

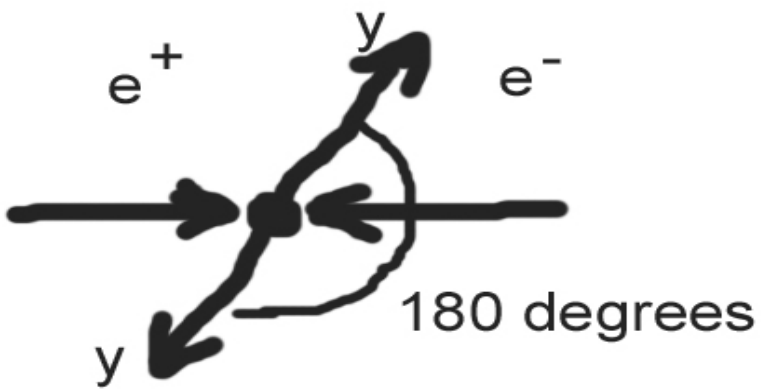
Principles

- Positron Emissions:
  - Annihilation Reaction

$$ {}^{A}_{Z}X_{N} \rightarrow {}^{A}_{Z-1}Y_{N+1} + e^{+} + \nu $$

$$ e^{+} + e^{-} \rightarrow \gamma + \gamma $$

γ = 511 keV



Principles

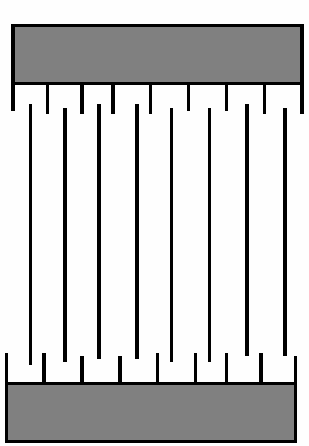
- Coincidence Detection:
  - Each annihilation reaction produces two photons 180 deg opposite of each other and 511 keV each. Both photons strike detectors simultaneously.
  - LOR: line of reference is drawn between the crystals that were hit by the pair of photons.

Instrumentation

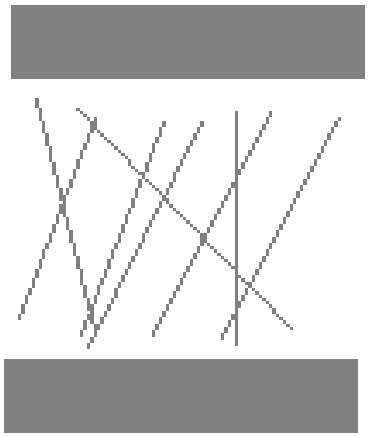
- Early Gamma Cameras and Hybrid Systems
  - Utilization of High Energy Collimators with conventional analog gamma cameras (not very successful) Scanning based on photon emissions only.
  - Coincidence Imaging (MCD) without collimators. Scanning based on coincidence. Attenuation correction applied as well.

Dedicated PET Systems

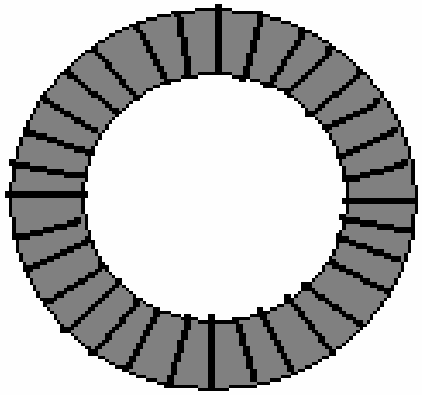
- Circular ring design with many crystals and PMT's around.
- Acquisition in 360 degrees done simultaneously.
- 2D (older) vs. 3D (newer) systems: Ability to image in many directions.



2D



3D



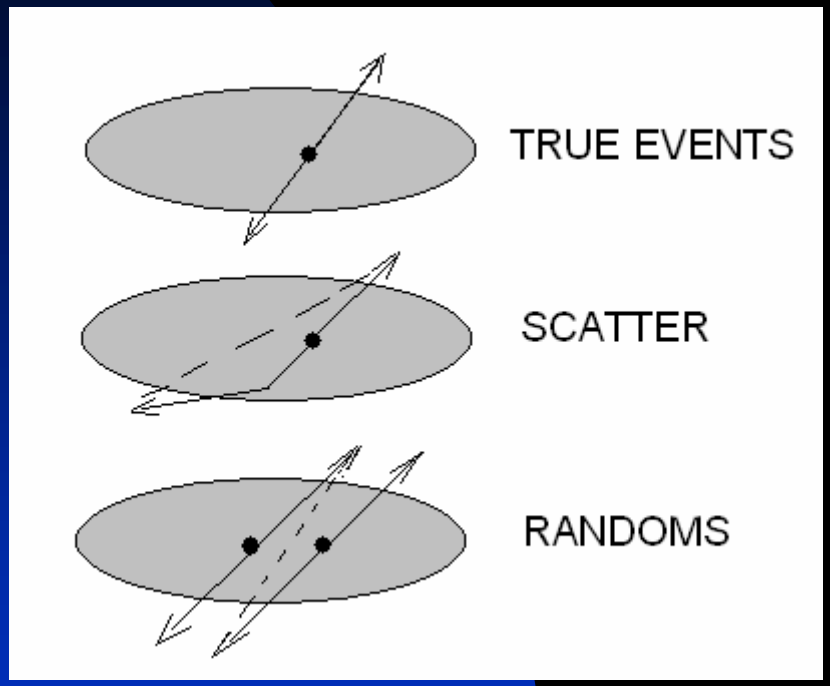
CIRCULAR RING DESIGN

Dedicated PET Systems

Types of Crystals:

- BGO: bismuth germanate. Most popular. Slow count rate, low energy resolution, good stopping power. (older systems).
- LSO (leutetium orthosilicate) and GSO (gadolinium orthsilicate). More efficient, fast scintillations. (new systems).

Image Acquisition



LOR: line of reference. Calculates the original position of the annihilation reaction

True evens (T): events that are properly recorded and an accurate LOR is calculated.

Scatter (S): one of the photons is deflected due to scatter. LOR is not calculated accurately.

Random events (R): two separate annihilation reactions occurring AT THE SAME TIME produce four photons that all hit the crystals. LOR calculation is not accurate. Time window (similar to cardiac gating window controls the amount of randoms.

P = T + S+ R (P= total counts)

T = P - S - R (true counts should always be maximized.

Emission and Transmission

- Emission: radiation that is emitted from the patient. Isotopes that are injected emit radiation (photons) that we acquire.
- Transmission: radiation that is directed through the body and is acquired on the opposite side to measure attenuation by the body. (example: X-rays, CT, and cobalt sheet source outlines).

Why are both important in PET? How does one compliment the other?

Imaging Artifacts

- Metallic Implants: prosthetics, implants, chemo pumps, pacemakers. Cause high degree of attenuation on transmission. Result: Emission is overcompensated causing false hot spots.
- Respiratory Motion: motion of the chest wall causes misplacement of transmission map over the emission map. Result: Linear cold spots.
- Contrast Media: same as metallic implants. Result: false hot spots.
- Truncation: large patients take up entire space in the bore of the machine. Attenuation correction map are inaccurate. Result: hot rim around the edges of the body.

Radiopharmacy

Common Isotopes:

1. C^{11} – 20min half-life — cyclotron produced
2. N^{13} – 9min half-life — cyclotron produced
3. O^{15} – 2.1min half-life — cyclotron produced
4. F^{18} – 110min half-life — cyclotron produced
5. Rb^{82} – 75sec half-life — generator produced

Radiopharmacy

FDG method of localization:

1. Similar to naturally occurring glucose.
2. Uptake is based on affinity for glucose by the target cells.
3. FDG undergoes normal glucose metabolism; however, does not finish it and stays trapped in the cytosol.

NORMAL GLUCOSE

1.glucose ->

2.Glucose–6-phosphate ->

3.Fructose–6-phosphate

FDG

1.FDG ->

2.FDG-6-phosphate -> X

3. no FDG-6-phosphate

Method of Localization – key points

- Malignancy (or anything hypermetabolic) = high degree of uptake.
- Inflammation and Infection may also show high uptake of FDG due to higher metabolism
- Therefore:
  - FDG = high sensitivity but low specificity

Patient Scheduling and Prep.

- NPO post midnight.
- No exercise for at least 24 hours.
- Glucose level checked and less than 200 mg/dL.
- Water intake allowed and will generally help wash extra FDG from soft tissues (think bone scans).
- No pregnant or breastfeeding patients.
- Relaxation meds may be helpful for mentally challenged patients.
- Diabetic patients should be scheduled as early as possible.

Procedure

- Medical history reviewed, procedure explained.
- Check sugar level with glucometer.
- For brain scans: dark room, running IV, no talking, eyes closed.
- For WB scans: empty bladder, inject, rest immediately after injection.
- Typical dose: 10-20 mCi FDG.
- Void before scanning.

Patient Positioning

- WB:
  - From base of brain down to mid-thigh.
  - Arms up recommended.
  - Use knee cushions and blankets.
  - No motion (straps maybe helpful).
  - Scan time = 45 mins.
- Brain:
  - Scout view taken to ensure brain positioning.
  - AC may or may not be used.
  - Arms down.
  - Scan time = 20 mins.

Image Findings (WB)

- Normal Findings:
  - HIGH ACTIVITY: BRAIN, LIVER, KIDNEYS, BLADDER.
  - LOW ACITIVITY: SALIVARY GLANDS, THYROID, HEART, SPLEEN, BOWEL, BONE MARROW, MUCLES, TESTICLES, ENDOMETRIUM.
- Abnormal:
  - Focal hot spots extending through anatomical structures (ex: lymphatic system, bowel, etc).

Pet Applications

- Solitary Pulmonary Nodules (SPN
- Non-Small Cell Lung CA (NSCLS
- Melanoma
- Lymphoma: NHL and HL.
- Colorectal CA
- Breast CA
- Brain CA
- Prostate CA
- Ovarian CA
- Testicular CA
- Thyroid CA

Image Fusion

- Originally began with SPECT brain and brain CT or brain MRI.
- Combines physiology and anatomy into one image.
- Allows images from different modalities to be fused together.
- Technical problems:
  - Patient motion
  - Breathing
  - Inability to replicate patient positioning
  - Operator dependent
  - Modalities may have compatibility issues

- PET/CT scanners:
  - Best possible design for successful image fusion.
  - Provides most efficient scan: CT = attenuation correction (transmission).
  - The same tech, machine, timeframe, positioning.