Introduction to Positron Emission Tomography

with your host, Terry Oakes
Positron Annihilation

Positron emitting atom

Positron range: 1-10 mm

Gamma-Ray range: 10 mm - $\infty$

neighboring atom

positron annihilation

180°
Positron Emission Tomography

detector ring

detector #1

\( \gamma \#1 \)

\( \gamma \#2 \)

detector #2
Positron Emission Tomography

detector #1

\[ \gamma \] #1

detector #2

\[ \gamma \] #2
Positron Emission Tomography
Positron Emission Tomography
Positron Emission Tomography
P.E.T. measures Concentration of Radioactivity

1) Gamma-rays escape from body:
   External detection possible.

2) Two gamma rays emitted at 180° when a positron annihilates:
   The annihilation occurred somewhere between the two detectors.

3) Regions with greater radioactivity levels produce more LORs:
   Concentration of radioactivity can be measured and quantified.
P.E.T. yields Quantitative results. ( $\mu$Ci/cc tissue )

Corrections must be applied to raw data:
1) Dead-time, Random events
2) Calibration
3) Normalization
4) Scatter-correction
5) Attenuation correction
6) Reconstruction
Corrections to Sinograms

raw sinogram (20 cm cylinder)

Normalized, without Scatter-Correction

trim (remove edges)

Scatter-Correct

mash (combine angular views)
## Effect of Corrections on Images

<table>
<thead>
<tr>
<th>Scatter-corrected</th>
<th>Normalized</th>
<th>Attenuation-corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Scatter-corrected Image" /></td>
<td><img src="image2" alt="Normalized Image" /></td>
<td><img src="image3" alt="Attenuation-corrected Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>X</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scatter-corrected</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Normalized</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Attenuation-corrected</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Color Scale**

- Uniform
- 20 cm cylinder
Measure response of the PET scanner to a known concentration of radioactivity.

Obtain Calibration Factor applicable for all scans. (CF ~ (µCi/cc)/counts)
Normalization
Normalization

Individual detectors respond differently to the same level of radioactivity.

Normalization produces a uniform response to the same level of radioactivity.
Attenuation Correction

Gamma-ray attenuation proportional to:
1) density of object
2) pathlength through object

Attenuation can be corrected with a density-weighted map of the object.

Attenuation causes a non-uniform loss of events; more gamma rays passing through the middle of the object are lost.
Scatter Correction

Scattered gamma rays cause recorded events to be mispositioned.

Scatter tends to increase the concentration measured toward the center of the object.
PET Data Acquisition

Radioactive source in PET scanner

raw sinogram
P.E.T. data are acquired as discrete Lines of Response (LORs)

Angular View #1
(theta = 0)

Angular View #2
(theta = 45)

Angular View #3
(theta = 90)
Three Angular Views

Angular View #1
(theta = 0)

Angular View #2
(theta = 45)

Angular View #3
(theta = 90)
Angular View #1 (theta = 0)
Angular View #2 (theta = 45)
Angular View #3 (theta = 90)

Sinogram

Angular views
radial bins
Image Reconstruction

raw sinogram → it’s magic! → Reconstructed Image