Introduction to Positron Emission Tomography

with your host, Terry Oakes

Positron Annihilation

\[ \gamma \#1 \quad 180^\circ \quad \gamma \#2 \]
Positron Annihilation

Positron emitting atom

Positron range: 1-10 mm

Gamma-Ray range: 10 mm - ∞

neighboring atom

180°

positron annihilation

γ #1

γ #2

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Positron Emission Tomography

detector ring

detector #1

$\gamma$ #1

detector #2

$\gamma$ #2
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) → trim (remove edges) → Scatter-Correct

Normalized, without Scatter-Correction → Normalize (combine angular views)
Effect of Corrections on Images

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

Uniform 20 cm cylinder

color scale

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Calibration

Converting “counts/pixel” to “microCi / cc tissue”

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

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

Individual detectors respond differently to the same level of radioactivity.

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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.

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Scatter Correction

Scattered gamma rays cause recorded events to be mispositioned.

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

Gamma-ray scattered

Unscattered (true) events

Scattered events

Radial bin

Number of events

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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)

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Angular View #1 (theta = 0)

Angular View #2 (theta = 45)

Angular View #3 (theta = 90)

Sinogram

radial bins

angular views
Image Reconstruction

raw sinogram

it’s magic!

Reconstructed Image