Medical Image Processing for Diagnostic Applications

Modalities – PET and SPECT

Online Course – Unit 52
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Topics

Positron Emission Tomography

Single Photon Emission Computed Tomography

Summary

- Take Home Messages
- Further Readings

Positron Emission Tomography (PET)

- PET is based on the insertion of a radioactive substance (e. g., isotopes $^{15}\mathrm{O}$, $^{11}\mathrm{C}$, $^{13}\mathrm{N}$, or $^{18}\mathrm{F}$) into the patient's body via injection, inhalation, or ingestion.
- The radioactive substance is bound to a molecule that is of interest for the diagnostic task (e. g., sugar for analysis of the patient's metabolism).
- The imaging task delivers a map of the distribution of the radioactive tracer.

Positron Emission Tomography: Concept

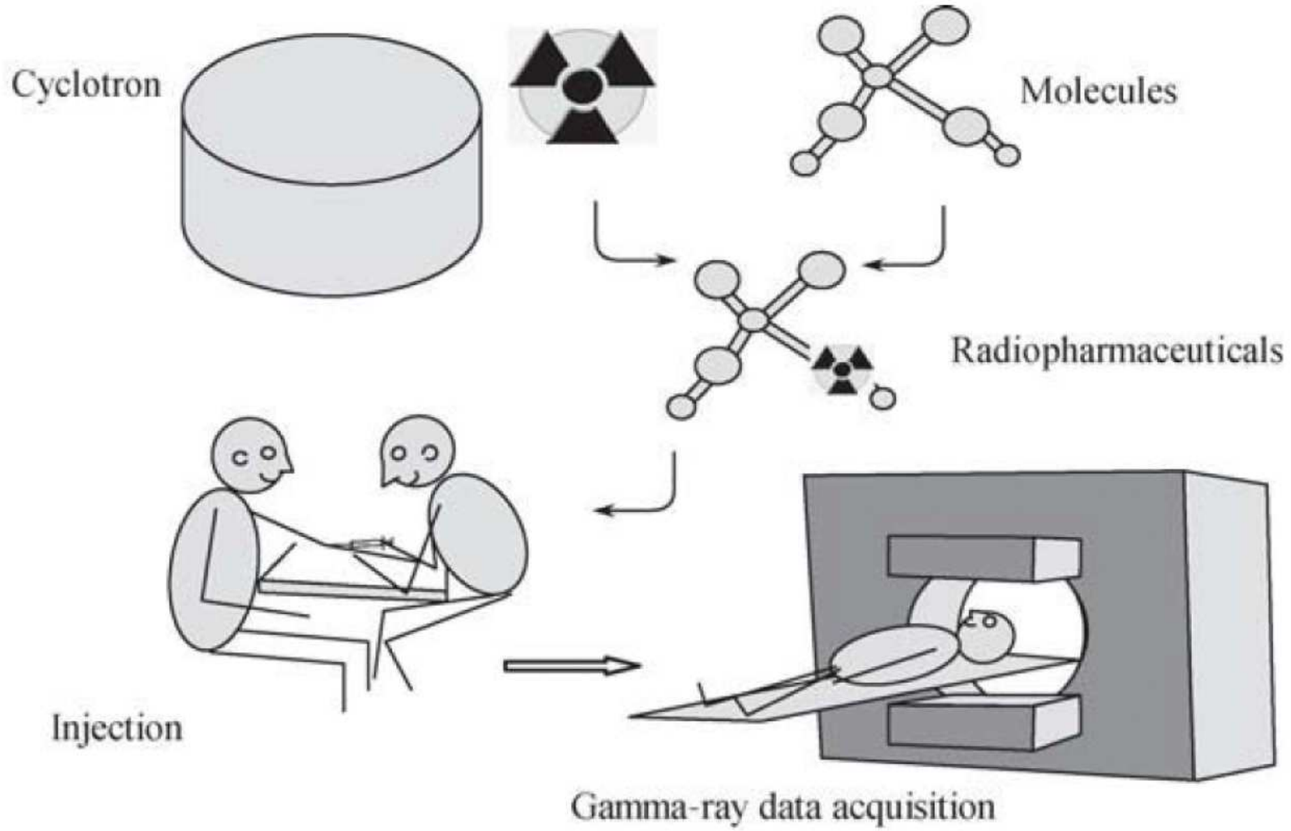


Figure 1: Scheme of a PET scan workflow (Zeng, 2009)

Positron Emission Tomography: Physics

- The radio decay of the isotopes causes the creation of positrons.
- As soon as a positron hits an electron, their masses are annihilated, and two photons of 511 keV each are emitted into opposite directions.

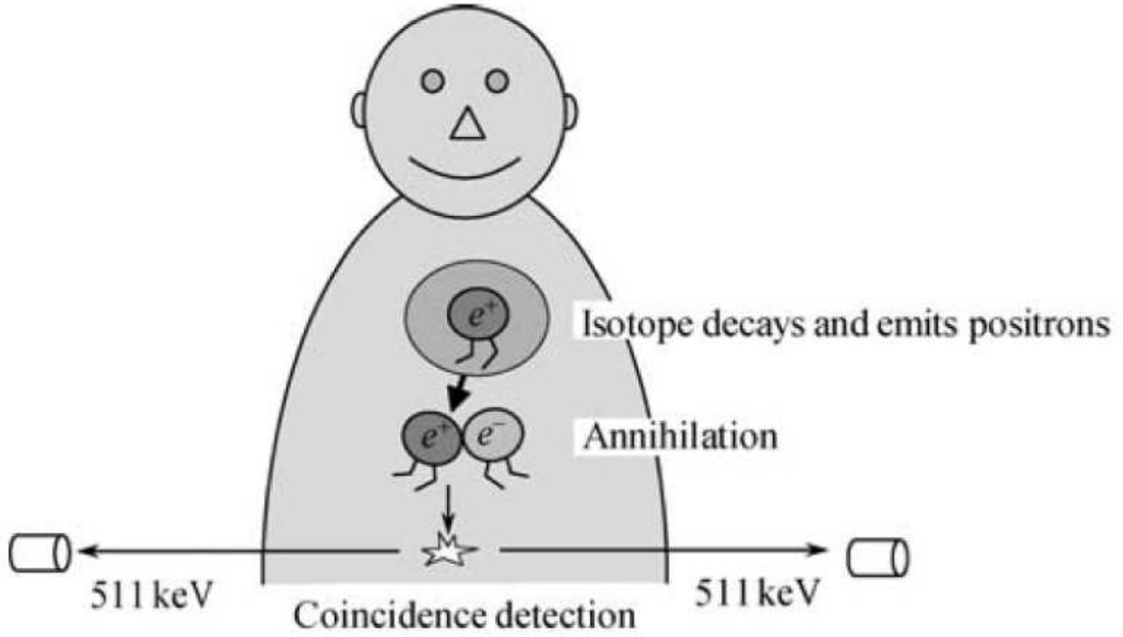


Figure 2: Illustration of positron annihilation (Zeng, 2009)

Positron Emission Tomography: Acquisition Geometry

- Simultaneous events have to be detected in order to find a pair annihilation.
- As the direction of the gamma rays is on the same line, but in opposite direction, a parallel imaging geometry emerges.

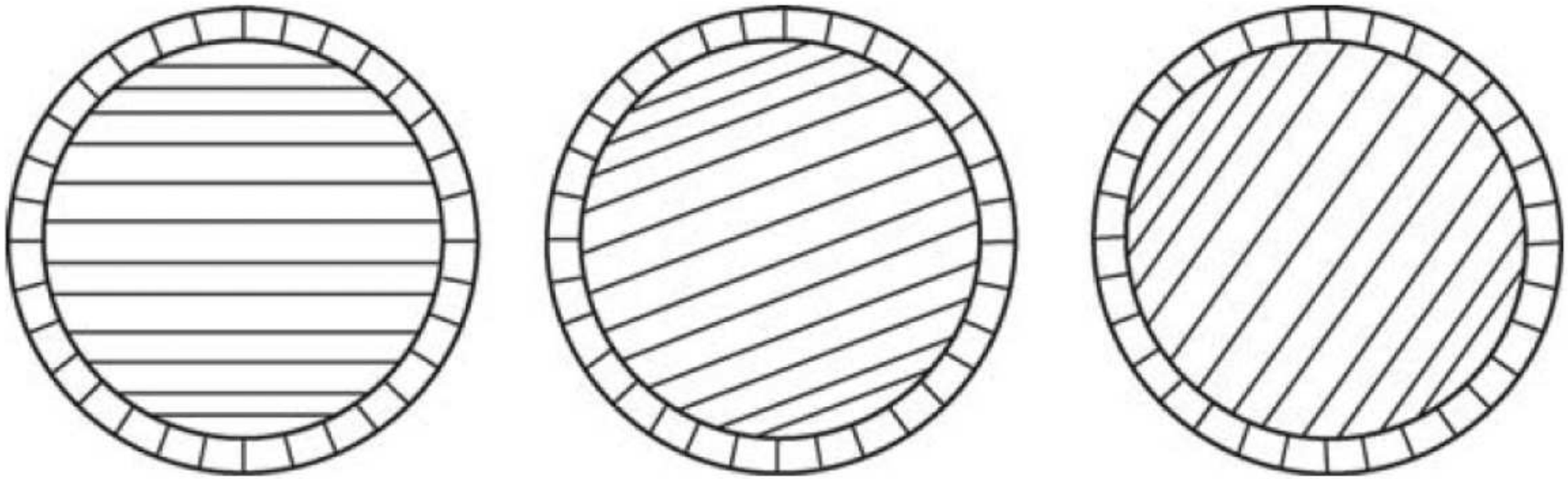


Figure 3: Illustration of the parallel line acquisition in PET (Zeng, 2009)

Positron Emission Tomography

- PET imaging has lower resolution than X-ray imaging.
- PET scans show the concentration of the tracer substance.
- Time-of-flight imaging helps to increase the spatial resolution of PET scans.
- Attenuation correction helps to reduce image distortions.

Figure 4: PET torso image (inverse gray scale, Zeng, 2009)

Positron Emission Tomography: Attenuation Correction

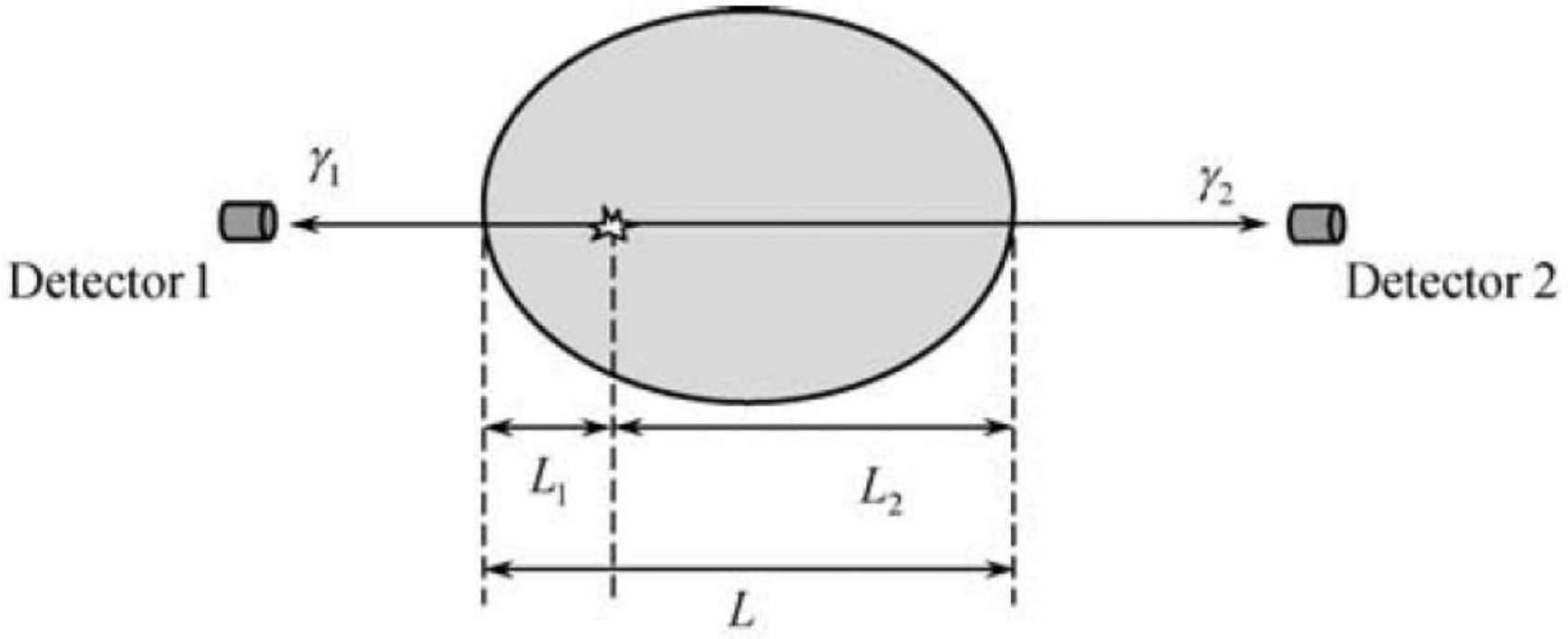


Figure 5: Depending on the point of emission, the positrons may have different path length to the detectors (Zeng, 2009).

Topics

Single Photon Emission Computed Tomography (SPECT)

- SPECT (like PET) is based on the insertion of a radioactive substance into the patient's body via injection, inhalation, or ingestion.
- Analogously, the radioactive substance is bound to a molecule that is of interest for the diagnostic task (e. g., sugar for analysis of the patient's metabolism).
- The imaging task also delivers a map of the distribution of the radioactive tracer.
- However, the detected ray energy consists of collimated gamma rays in contrast to PET where coincident photons are measured, induced by positron annihilation.

Single Photon Emission Computed Tomography: Principle

- Radioactive decay causes the emission of gamma rays.
- The emitted gamma quanta are detected by a gamma camera.
- Only single gamma rays are seen by the camera.
- The imaging geometry is determined by the system's collimator.

Single Photon Emission Computed Tomography: Principle

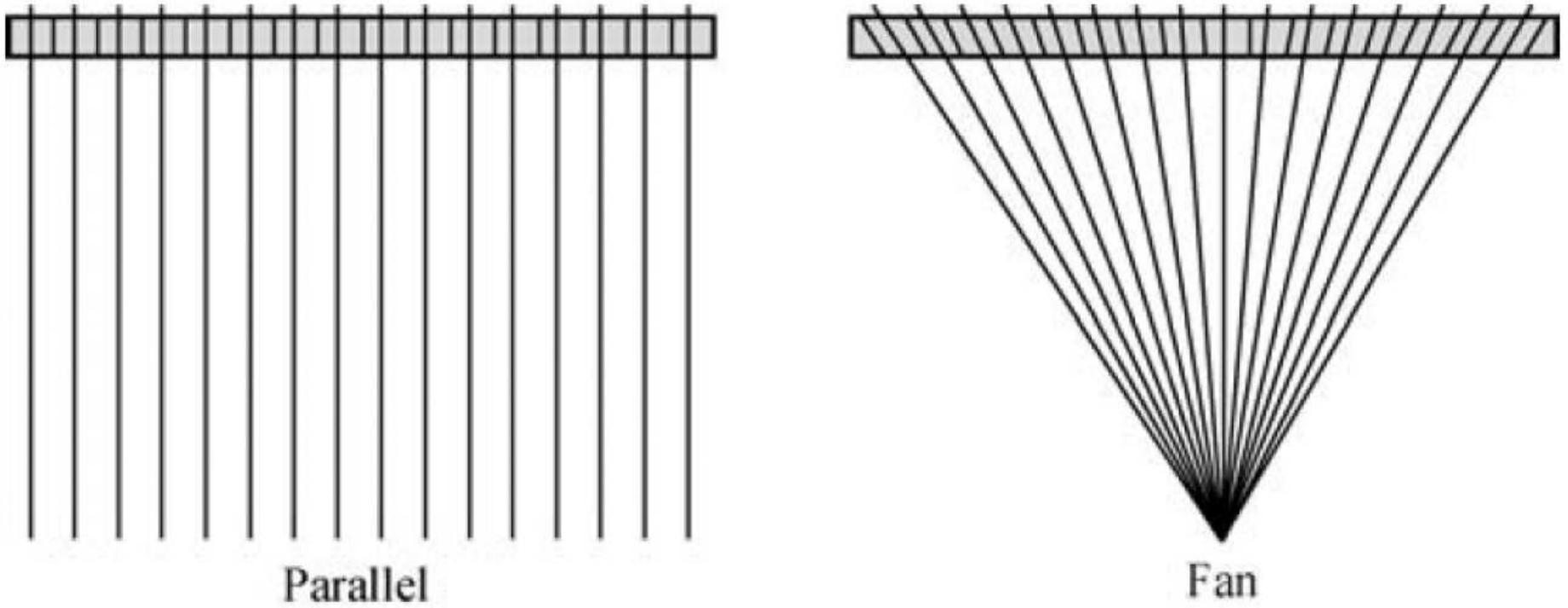


Figure 6: Among others, there are parallel and fan beam collimators for SPECT (Zeng, 2009).

Single Photon Emission Computed Tomography: Collimators

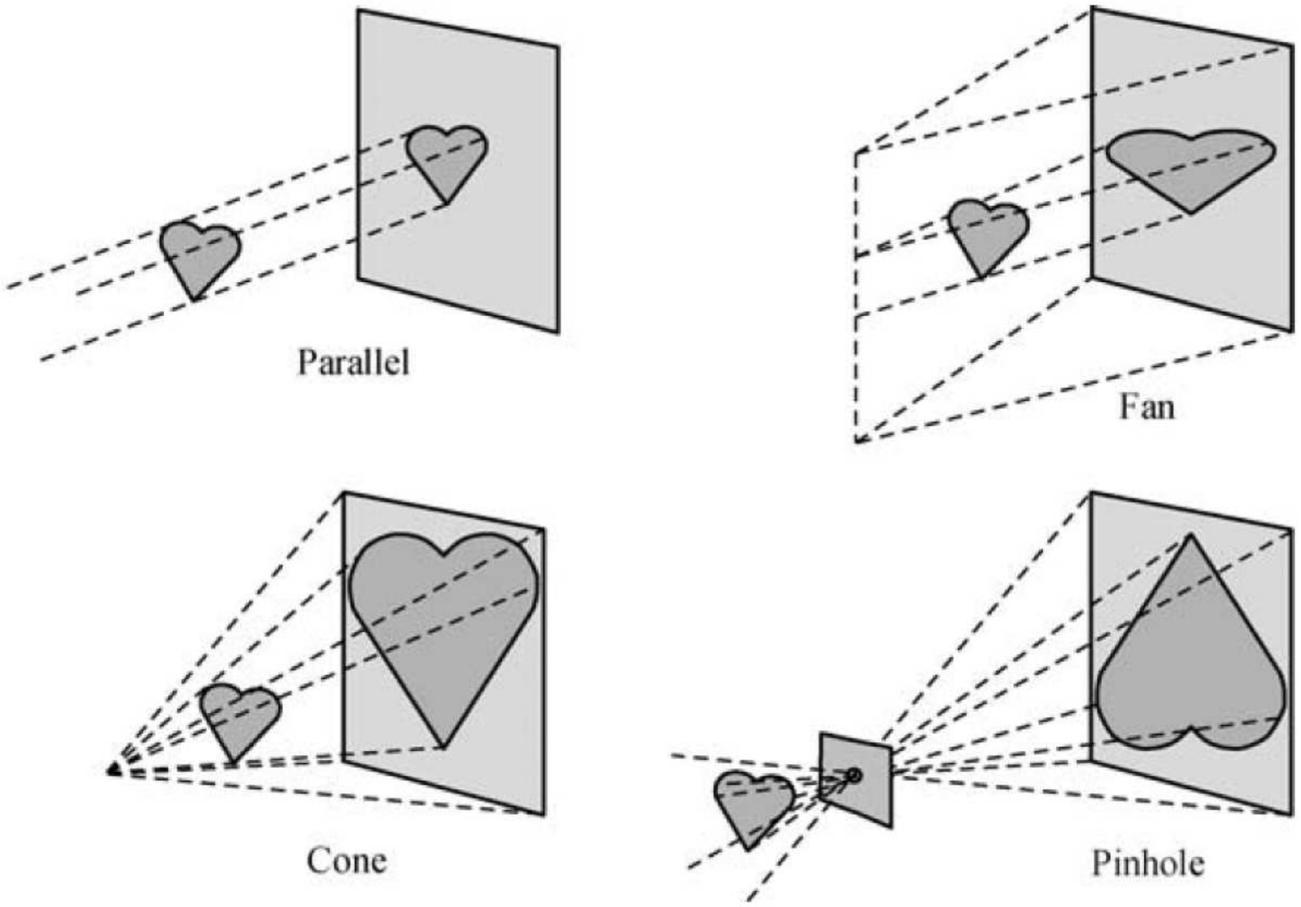


Figure 7: The imaging result is dependent on the collimator type (Zeng, 2009).

Single Photon Emission Computed Tomography

- SPECT imaging has a lower resolution than PET imaging.
- SPECT scans show the concentration of the tracer substance.
- Attenuation correction helps to reduce image distortions.

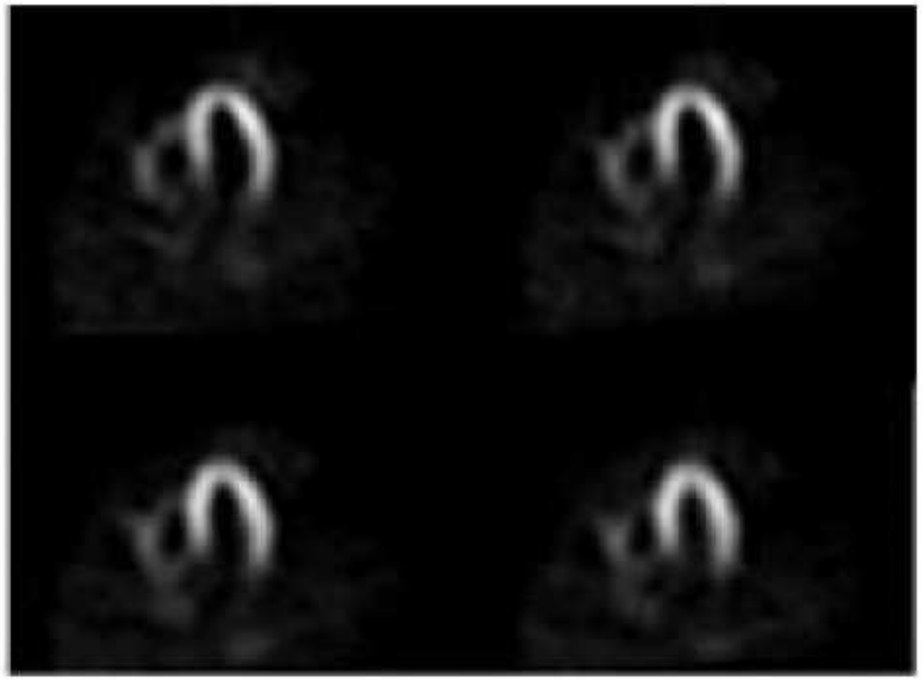
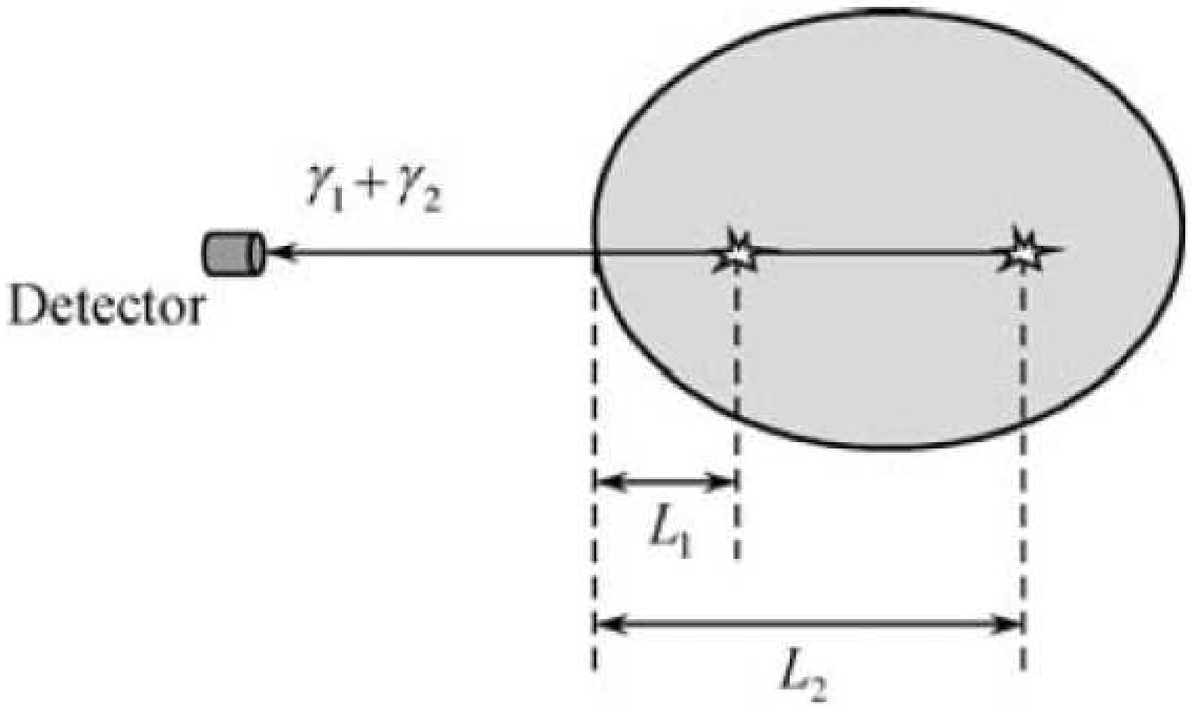


Figure 8: SPECT cardiac images (Zeng, 2009)

Single Photon Emission Computed Tomography: Attenuation Correction



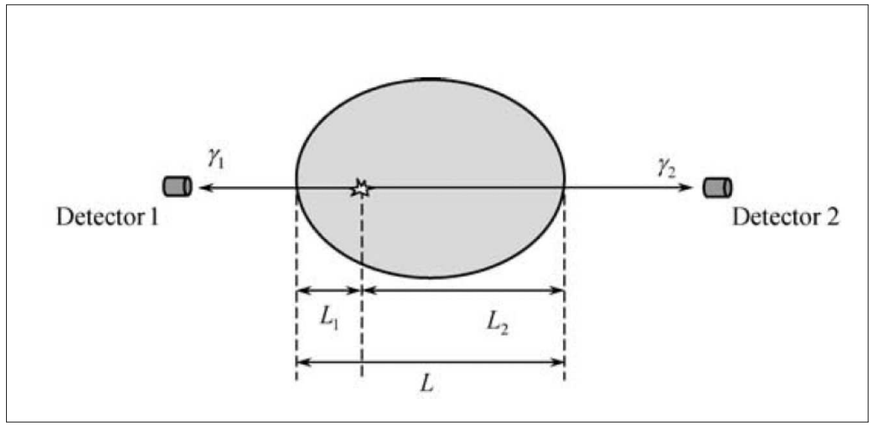


Figure 9: Attenuation correction for SPECT (left) vs. attenuation correction for PET (right box) (Zeng, 2009)

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Take Home Messages

- PET and SPECT both are based on the detection of gamma rays emitted from radioactive substances *inside* the patient's body.
- Every modality has its strengths and its weaknesses $\rightarrow$ PET and SPECT show functional images.
- Combination of modalities helps to alleviate particular problems $\rightarrow$ hybrid systems, e. g., SPECT/CT and PET/MR, are emerging technologies.

Further Readings

Two reads for more insight into modalities:

Avinash C. Kak and Malcolm Slaney. *Principles of Computerized Tomographic Imaging*. Classics in Applied Mathematics. Accessed: 21. November 2016. Society of Industrial and Applied Mathematics, 2001. DOI: 10.1137/1.9780898719277. URL: http://www.slaney.org/pct/

Gengsheng Lawrence Zeng. *Medical Image Reconstruction – A Conceptual Tutorial*. Springer-Verlag Berlin Heidelberg, 2010. DOI: 10.1007/978-3-642-05368-9