Advantages of PET Myocardial Imaging
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Purpose

- Review the physics and hardware of cardiac PET and compare with SPECT
- Demonstrate and understand the profound differences between the capabilities of PET vs. SPECT
- Review currently available cardiac tracers
Positron Emission Tomography: Basic Principle

Image courtesy of wikipedia_PET-schema accessed March 2016
PET Instrumentation


Conventional SPECT

- Limited count sensitivity
- Limited energy resolution
- Limited spatial and contrast resolution
- Limited accuracy of measuring uptake without AC

Camera Specifications

PET
- 511KeV photons
- LIST mode (most)
- >3 Million counts/sec
- ~35 M counts/study
- Sensitivity (detection of emitted photons) 2-15%
- Spatial resolution <2-3mm

SPECT
- Photon energies <140KeV
- Binned mode (most)
- 500-3000 counts/sec
- 7-10 M counts/study
- Sensitivity 2-3x less than PET → longer acquisition
- Spatial resolution 6-11 mm

Note: numbers refer to reference list at the end of this presentation
27. Saha GB. Basics of Pet Imaging. Springer-Verlag 2010
Attenuation Correction (AC)

- Photon attenuation results from emitted radiation interacting with tissue.
- For PET, because it is dual-photon, attenuation is independent of the point of origin along the line of response (LOR). Therefore, with AC, one can accurately quantify radiotracer activity.
- For SPECT, due to its single-photon emission, attenuation changes are dependent on the point of emission. Therefore, with AC, one cannot accurately quantify radiotracer activity.
Attenuation Correction (AC)
Advantages of PET

- PET scanners have built-in attenuation correction
- Superior resolution due to count sensitivity
- Image quality and quantification are functions of counts/time
Quantification of Flow

- Extent of CAD is inversely proportional to myocardial flow; lower the flow → more CAD is present
- PET technology provides for higher detected count rates over shorter time frames
- Radiotracers are extracted from the blood into the myocardium
- PET can quantify the rate of blood flow to myocardium; expressed in mL/min/g
- FDA-approved software models for Rb-82 and N-13
PET Cardiac Tracers

- Currently Available
  - Rubidium-82 Chloride (perfusion)
  - N-13 Ammonia (perfusion)
  - F-18 FDG (viability)
- In Clinical Trials
  - F-18 labeled agents
  - 0-15 Water (IND only)
Common Cardiac PET Tracers

- The shorter the half-life, the less radiation exposure
- SPECT tracers have longer half-lives and higher radiation exposure

<table>
<thead>
<tr>
<th>Tracer</th>
<th>Half Life</th>
<th>Dose Range</th>
<th>Production Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rb-82</td>
<td>75 sec</td>
<td>20–60 mCi</td>
<td>Generator</td>
</tr>
<tr>
<td>N-13 Ammonia</td>
<td>9.8 min</td>
<td>7–20 mCi</td>
<td>Cyclotron</td>
</tr>
<tr>
<td>F-18 FDG</td>
<td>109.8 min</td>
<td>5-15 mCi</td>
<td>Cyclotron</td>
</tr>
</tbody>
</table>

Rest/stress Rb-82 protocols can be accomplished in 30-45 minutes.

Rb-82 20-60 mCi

CT transmission

gated rest

pharmacologic stress

gated stress

CT transmission

Approx 1 min

Approx 7 min

Approx 6 min

Approx 7 min

Approx 1 min

15. Gary Heller and Robert Hendel. Handbook of Nuclear and Cardiac PET. Cardiology: Cardiac SPECT
Cardiac PET Imaging in a Contemporary Clinical Practice

Cardiac PET provides important information pertaining to 3 critical aspects of cardiac diagnosis and management

1. Diagnosis
   - In patients suspected of having CAD because of chest discomfort, dyspnea, arrhythmias, cardiac risk factors, or other clinical findings including acute coronary syndromes

2. Prognosis
   - Extent of ischemia, infarct and viability correlates well with prognosis
   - Risk stratification into subgroups

3. Response to Therapy
   - Adequacy of revascularization
   - Medical reduction of ischemia

Pharmacokinetics and Physics: Benefits of Cardiac PET MPI

- PET MPI uses higher energy tracers (511keV vs. 140KeV for SPECT) with low radiation exposure\(^{11}\)
  - Leads to higher count rates and improved image quality\(^ {1-4}\)
- PET MPI tracers (Rb-82 & N-13 Ammonia) have a high myocardial extraction fraction at peak stress flow\(^ {1,9-10}\)
  - Tracer uptake is more proportional to myocardial blood flow; facilitates better detection of disease
- PET MPI offers attenuation correction on all scans\(^ {1,4-5}\)
  - Reduces ambiguity, enhances interpretive certainty

4. Bateman. Amer J Cardiol 2004
5. Gould, KL. Circulation 1994
What Are the Advantages of Cardiac PET MPI Imaging?

- **Image Quality, Diagnostic Accuracy, Interpretive Certainty**\(^1-5\)
  - Excellent spatial resolution and attenuation correction
  - 95% sensitivity, 95% specificity
  - Better images = greater diagnostic confidence
  - Potential to lower utilization of downstream invasive procedures and associated costs

- **Efficiency**\(^1-2,4\)
  - 30-45 min. complete gated rest / stress studies

- **Prognostic Value, Risk Stratification**\(^3,6\)
  - Useful for making patient management decisions

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4. Bateman. Amer J Cardiol 2004
5. Gould KL. Circulation 1994
Summary

- The physics of PET and attributes of the tracers are optimal for MPI\(^1\)-\(^5\), \(^9\)-\(^10\).
- Cardiac PET addresses the need for improved interpretive certainty and greater efficiency\(^1\)-\(^4\).
- Cardiac PET performs well even with challenging patient types (e.g., pharm stress, obese, female) and more accurately identifies multi-vessel disease\(^1\),\(^3\)-\(^4\),\(^6\),\(^7\),\(^16\).
- PET can help improve the management of patients with known or suspected CAD and heart failure\(^1\)-\(^3\),\(^6\),\(^7\),\(^17\)-\(^22\).
- Quantification of myocardial blood flow adds incremental prognostic value\(^17\),\(^21\),\(^22\).
- Use of PET can help to implement a strategy for the reduction of radiation exposure from cardiac imaging procedures\(^24\)-\(^25\).
References


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Important Safety Information

- Image interpretation errors can occur with PET imaging. A negative image does not rule out recurrent prostate cancer and a positive image does not confirm its presence. Clinical correlation, which may include histopathological evaluation, is recommended.

- Hypersensitivity reactions, including anaphylaxis, may occur in patients who receive PET radiopharmaceuticals. Emergency resuscitation equipment and personnel should be immediately available.

- PET/CT imaging contributes to a patient’s overall long-term cumulative radiation exposure, which is associated with an increased risk of cancer. Safe handling practices should be used to minimize radiation exposure to the patient and healthcare providers.

- Adverse reactions, although uncommon, may occur when using PET radiopharmaceuticals. Always refer to the package insert prior to use.