DETAIL

DEMONSTRATING EXCELLENCE THROUGH
ADVANCED IMAGING LEARNING

MITA®
MEDICAL IMAGING
& TECHNOLOGY ALLIANCE
A DIVISION OF NEMA

Advantages of PET Myocardial Imaging

Legal Disclaimers

DETAIL

DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

These materials were prepared in good faith by MITA as a service to the profession and are believed to be reliable based on current scientific literature. The materials are for educational purposes only and do not replace either the need for individualized patient diagnosis and treatment planning by qualified physicians based on existing good practices or the need for implementation by qualified radiologists or other qualified healthcare practitioners. Neither MITA nor its members are responsible for any diagnostic or treatment outcomes. MITA, its members, and contributors do not assume any responsibility for the user's compliance with applicable laws and regulations. MITA does not endorse the proprietary products or processes of any one company.

Purpose

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

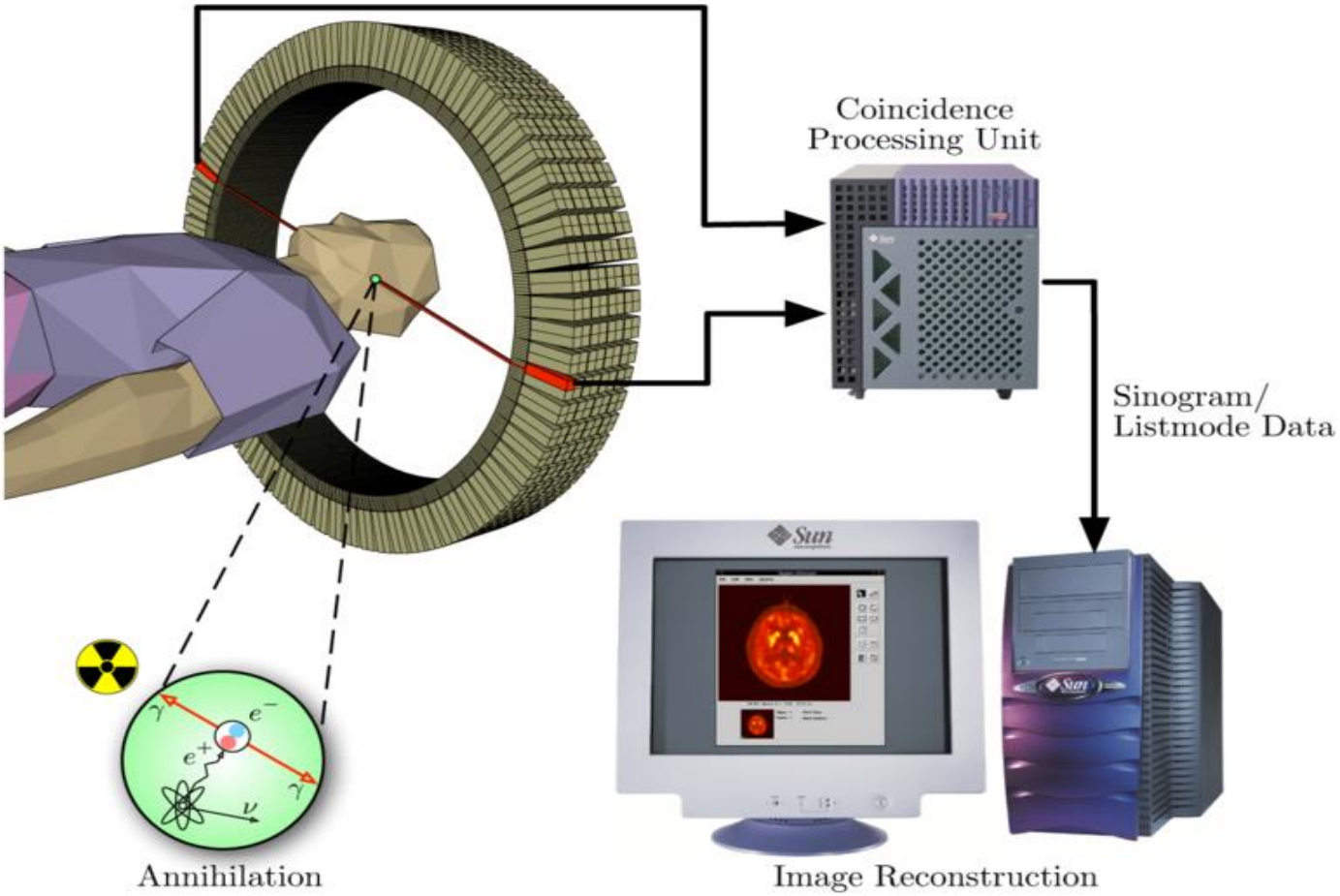


Image courtesy of wikipedia_PET-schema accessed March 2016

PET Instrumentation

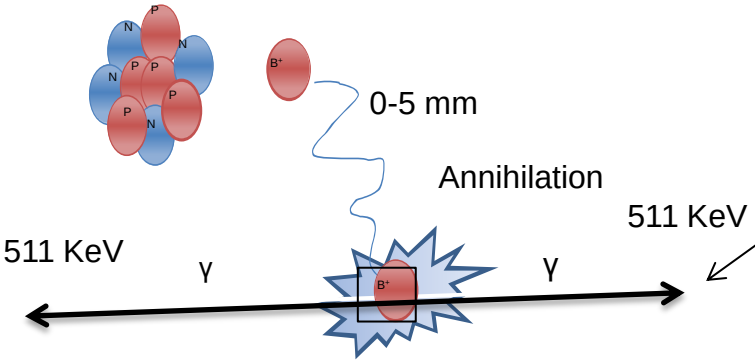
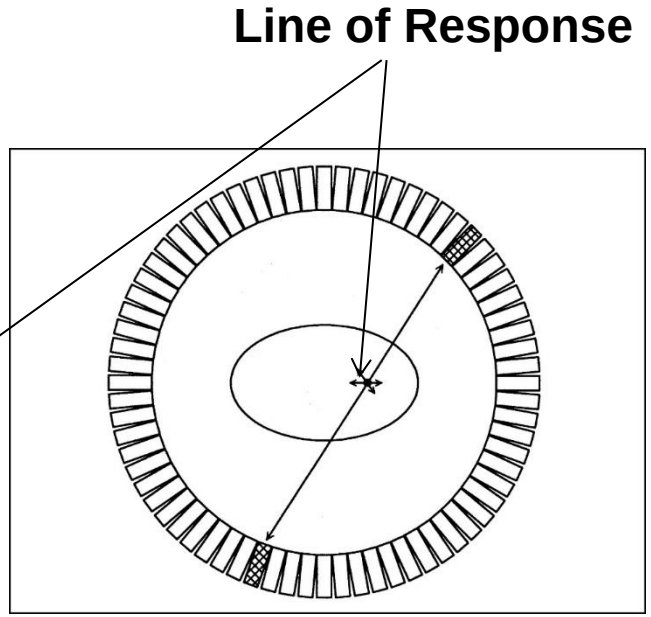


Image from: Lundbye J. Cardiac PET. In: Heller GV, Hendel RC. Handbook of Nuclear Cardiology. Springer; 2013.



Coincidence Event Detected in Ring PET Scanner

Image originally published in Turkington TG. J Nucl Med Technol 2001; 29(1):4-11

Conventional SPECT

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

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

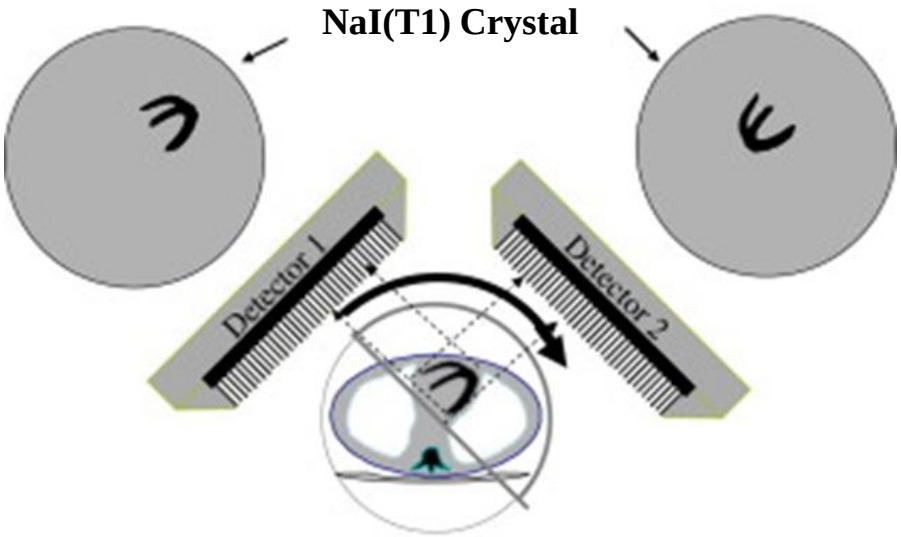


Image from: Garcia EV, et al. Cardiol Clin 2009; 27(2):227-236

Camera Specifications

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

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

26. Wackers F. Amer Coll Cardiol 2010; 55(18):1975-78
27. Saha GB. Basics of Pet Imaging. Springer-Verlag 2010
28. Gould et al. J Am Coll Cardiol 2013; 62:1639–53
29. Salerno M and Beller G. Circ Cardiovasc Imaging 2009; 2:412-424

Attenuation Correction (AC)

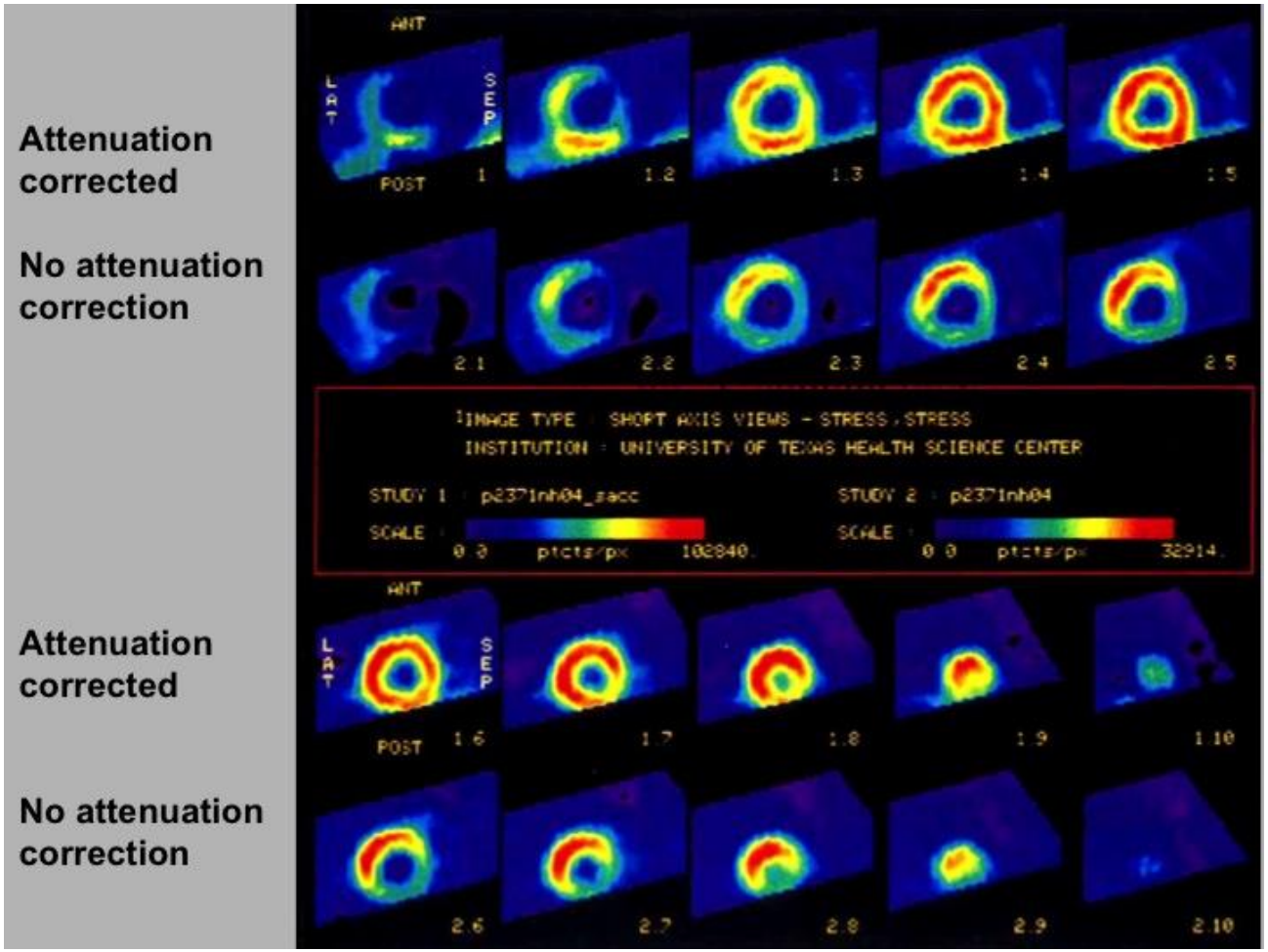
DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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)

DETAIL

DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING



Courtesy of K. Lance Gould, MD

Advantages of PET

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

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

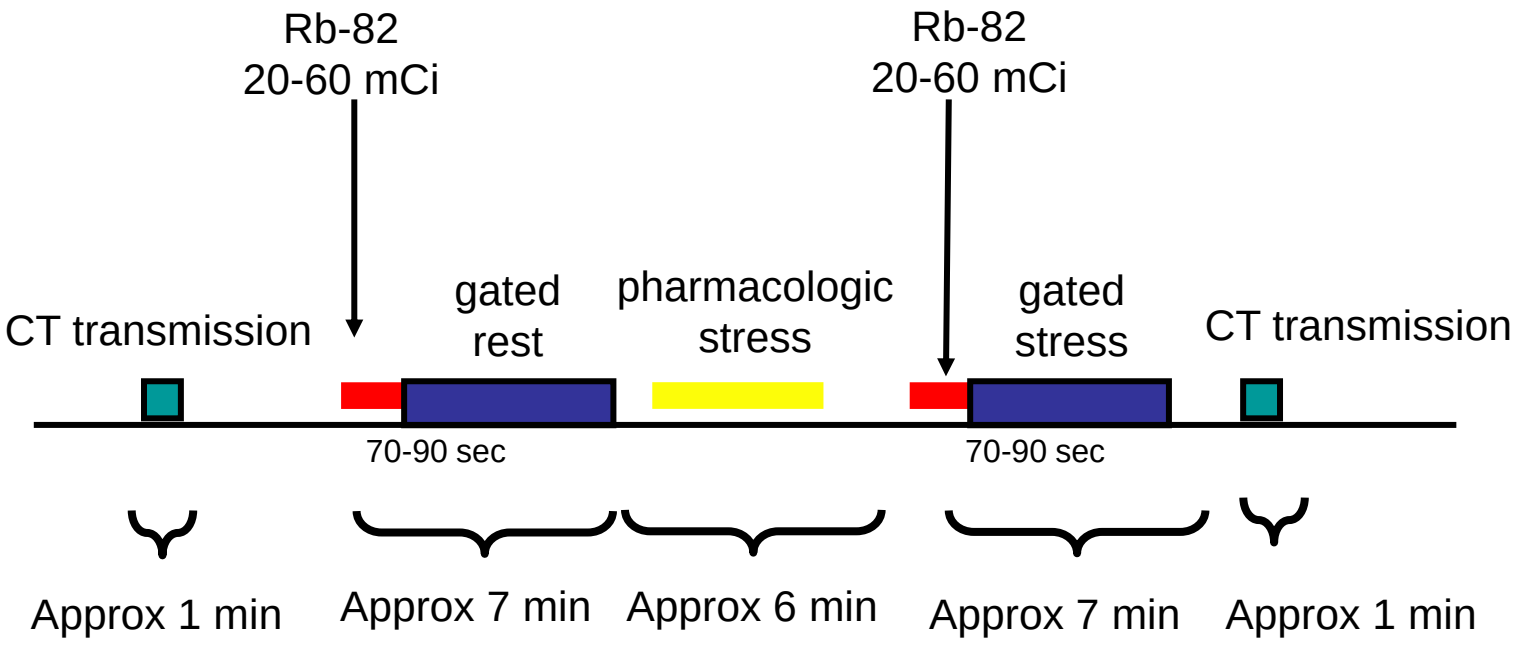
Tracer	Half Life	Dose Range	Production Method
Rb-82	75 sec	20–60 mCi	Generator
N-13 Ammonia	9.8 min	7–20 mCi	Cyclotron
F-18 FDG	109.8 min	5-15 mCi	Cyclotron

8. Nuclear Medicine Self-Study Program III: Nuclear Medicine Cardiology. Botvinik EH, Ed. 1998. SNM

Protocol – Patient Convenience

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

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



15. Gary Heller and Robert Hendel. Handbook of Nuclear and Cardiac PET. Cardiology: Cardiac SPECT

Cardiac PET Imaging in a Contemporary Clinical Practice

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

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

30. Heller G, et al. ASNC Model Coverage Policy: Cardiac PETJ Nucl Cardiol 2013; 20(5);916–47

Pharmacokinetics and Physics: Benefits of Cardiac PET MPI

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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

1. Bateman, et. al. J Nucl Cardiol 2006
2. Merhige, et al. J Nucl Med. 2007
3. Yoshinaga, et al. JACC. 2006
4. Bateman. Amer J Cardiol 2004
5. Gould, KL. Circulation 1994
9. Mullani NM. J Nucl Med 1983
10. Dilsizian V. Atlas of Nuclear Cardiology 2003
11. Senthamizhchelvan S, et al. JNM 2010; 51(10):1592–1599

What Are the Advantages of Cardiac PET MPI Imaging?

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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

1. Bateman, et. al. J Nucl Cardiol 2006
2. Merhige, et al. J Nucl Med 2007
3. Yoshinaga, et al. JACC 2006
4. Bateman. Amer J Cardiol 2004
5. Gould KL. Circulation 1994
6. Chow, et al. J Nucl Med 2005

Summary

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

1. Bateman TM, Heller GV, McGhie IA, et. al. Diagnostic accuracy of rest/stress ECG-gated Rb-82 myocardial perfusion PET: Comparison with ECG-gated Tc-99m sestamibi SPECT. J Nucl Cardiol 2006; 13:24-33
2. Merhige ME, Breen WJ, Shelton V, et al. Impact of myocardial perfusion imaging with PET and (82)Rb on downstream invasive procedure utilization, costs, and outcomes in coronary disease management. J Nucl Med 2007; 48:1069-1076
3. Yoshinaga K, Chow BW, Williams K, et. al. What is the prognostic value of myocardial perfusion imaging using rhubidium-82 positron emission tomography? J A Cardiol 2006; 48:1029-39
4. Bateman TM. Cardiac positron emission tomography and the role of adenosine pharmacologic stress. Amer J Cardiol 2004; 94:19-24
5. Gould KL. Reversal of coronary atherosclerosis: Clinical promise as the basis for non-invasive management of coronary artery disease. Circulation 1994; 90:1558-1571

References

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

6. Chow BJ, Wong JW, Yoshinaga K, et. al. Prognostic significance of dipyridamole-induced ST depression in patients with normal 82Rb PET myocardial perfusion imaging. J Nucl Med 2005; 46:1095-1101
7. ASNC Model Coverage Policy: Cardiac positron emission tomographic imaging. J Nucl Cardiol 2013; 20:916-47
8. Nuclear Medicine Self-Study Program III: Nuclear Medicine Cardiology. Botvinik EH, Ed. 1998: Society of Nuclear Medicine, Reston, VA
9. Mullani NM, Goldstein RA, Gould KL, et. al. Myocardial perfusion with rubidium-82. Measurement of extraction fraction and flow with external detectors. J Nucl Med 1983; 24:898-906
10. Dilsizian V, Narula J, Braunwald E, Eds. Atlas of Nuclear Cardiology. Current Medicine Inc. 2003. ISBN 978-1-4615-6496-6
11. Machac et al. PET myocardial perfusion and glucose metabolism imaging. J Nucl Cardiol 2006; 13:e121-51

References

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

12. Dorbala S, Vangala D, Sampson U, et al. Value of Vasodilator Left Ventricular Ejection Fraction Reserve in Evaluating the Magnitude of Myocardium at Risk and the Extent of Angiographic Coronary Artery Disease: A 82Rb PET/CT Study. J Nucl Med 2007; 48:349-358
13. McArdle BA, et al, Does Rubidium-82 Have Superior Accuracy to SPECT Perfusion Imaging for the Diagnosis of Obstructive Coronary Disease? J Am Coll Cardiol 2012; 60(18)
14. Dorbala S, et al, Prognostic Value of Stress Myocardial Perfusion Positron Emission Tomography: Results from a Multicenter Observational Registry. J Am Coll Cardiol 2013; 61(2):176-184
15. Gary Heller and Robert Hendel, Eds: Handbook of Nuclear Cardiology: Cardiac SPECT and Cardiac PET. Springer-Verlag London ©2013
16. Chow BJ, et al. Prognostic Value of PET Myocardial Perfusion Imaging in Obese Patients. JACC Cardiovascular Imaging 2014; 7(3)

References

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

17. Vasken Dilsizian and Jagat Narula. Atlas of Nuclear Cardiology, 3rd Edition, ©2009. Current Medicine Group LLC
18. DiCarli M, et al. Long Term Survival of Patients with Coronary Artery Disease and Left Ventricular Dysfunction: Implications for the Role of Myocardial Viability Assessment in Management Decisions. J Thorac Cardiovasc Surg 1998; 116(6):997-1004
19. D'Egidio G, et al, Increasing Benefit From Revascularization is Associated With Increasing Amounts of Myocardial Hibernation; A Substudy of the PARR-2 Trial. JACC Cardiovascular Imaging 2009; 2(9)
20. 2013 ACCF/ACR/ASE/ASNC/SCCT/SCMR Appropriate Utilization of Cardiovascular Imaging in Heart Failure. J Am Coll Cardiol 2013; 61(21)
21. Ziadi M, et al. Impaired Myocardial Flow Reserve on Rubidium-82 Positron Emission Tomography Imaging Predicts Adverse Outcomes in Patients Assessed for Myocardial Ischemia. J Am Coll Cardiol 2011; 58(7)

References

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

22. Murthy VL, et al. Improved Cardiac Risk Assessment with Non-Invasive Measures of Coronary Flow Reserve. Circulation 2011; 124(20):2215-2224
23. Skali H, Schulman A, and Dorbala S. 18-F FDG PET/CT for the Assessment of Myocardial Sarcoidosis. Current Cardiology Reports 2013; 15(4):352
24. Einstein AJ. Effects of Radiation Exposure From Cardiac Imaging: How Good Are the Data? J Am Coll Cardiol 2012; 59(6):553-565
25. Cerqueira MD, et al. ASNC Information Statement: Recommendations for reducing radiation exposure in myocardial perfusion imaging. J Nucl Cardiol; pub. online 26 May 2010
26. Wackers F. Cardiac Single-Photon Emission Computed Tomography Myocardial Perfusion Imaging Finally Up to Speed? J Amer Coll Cardiol 2010; 55(18):1975-78

References

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

27. Saha GB. Basics of Pet Imaging. Springer-Verlag New York 2010. ISBN 978-1-4419-0805-6
28. Gould KL, Johnson NP, Bateman TM, et al. Anatomic Versus Physiologic Assessment of Coronary Artery Disease Role of Coronary Flow Reserve, Fractional Flow Reserve, and Positron Emission Tomography Imaging in Revascularization Decision-Making. J Am Coll Cardiol 2013; 62:1639–53)
29. Salerno M and Beller G. Noninvasive assessment of myocardial perfusion. Circ Cardiovasc Imaging 2009; 2:412-424
30. Heller G, Beanlands R, Merlino D, et al. ASNC Model Coverage Policy: Cardiac PET. J Nucl Cardiol 2013; 20(5)

Important Safety Information

DETAIL
DEMONSTRATING EXCELLENCE THROUGH ADVANCED IMAGING LEARNING

- 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.

F18 FDG USPI

Rb82 USPI

N13 Ammonia USPI