MYOCARDIAL FLOW RESERVE AND THE IMAGE ENHANCEMENT OF MYOCARDIAL SPECT STUDIES

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DISCLOSURE

I do not have a financial interest, arrangement or affiliation including receipt of any honoraria or expenses with a commercial organization that may have a direct interest in the subject matter of my presentation.
OBJECTIVES

1. Identify some technical differences between SPECT quantification of myocardial flow reserve and traditional myocardial perfusion SPECT

2. Describe the technologist’s role in optimizing image quality of myocardial SPECT studies

3. Apply common processing techniques to help optimize SPECT image quality
What is Myocardial Flow Reserve (MFR)?

How can we measure or quantify myocardial flow reserve in nuclear medicine?
WHAT IS MFR?

Myocardial Flow Reserve (MFR): (Definition¹)

- Reflects the amount of additional blood flow that can be supplied to the myocardium above resting/baseline blood flow levels

- In other words, when there is limited or lack of MFR, this suggests an inability to further increase myocardial blood flow → Due to maximum vasodilation of a stenotic vessel
HOW CAN WE MEASURE MYOCARDIAL FLOW RESERVE IN NUCLEAR MEDICINE?
NM TECHNIQUES FOR MEASURING MFR

- PET ($^{82}$Rubidium, $^{13}$N-Ammonia, $^{15}$O-$\text{H}_2\text{O}$)
- Dynamic SPECT ($^{99m}$Tc-MIBI, $^{99m}$Tc-Tetrofosmin)
WHAT IS DYNAMIC SPECT?

DYNAMIC CARDIAC SPECT:  (DEFINITION²)

• SPECT acquisition technique that tracks the dynamic flow of the radiopharmaceutical as it enters the bloodstream and localizes in the myocardium

• This dynamic projection data allows us to assess the temporal changes in tracer concentration within various segments of the heart, which can be used to estimate myocardial blood flow and myocardial flow reserve
WHAT ARE SOME DIFFERENCES BETWEEN DYNAMIC SPECT FOR MFR AND CONVENTIONAL MPI SPECT?
DYNAMIC SPECT:

- When combined with a conventional MPI SPECT, provides diagnostic information on myocardial perfusion at stress and rest, such as defect reversibility or infarct

- Provides additional quantitative information on myocardial blood flow and myocardial flow reserve

- Dynamic SPECT at stress can only be performed using pharmacological stress

- Requires a high speed SPECT acquisition, using a sensitive multi-detector camera or a dedicated cardiac SPECT camera (CZT)

CONVENTIONAL MPI:

- Provides diagnostic information on myocardial perfusion at stress and rest, such as defect reversibility or infarct

- Stress studies can be performed using physical exercise or pharmacological stress

- Imaged with a typical NaI SPECT camera
EXAMPLE MFR PROTOCOL

• Using a Conventional NaI Dual Head SPECT/CT Camera: (As per Hsu et al \textsuperscript{10})
  ➢ Must be capable of high speed SPECT acquisition
  ➢ 90 Degree Detector Configuration (L-Mode)
  ➢ LEHR, 64 x 64 matrix, Zoom = 1.78
  ➢ Can be acquired using back-and-forth rotations or continuous gantry rotations (at maximum speed of 10 seconds per rotation)
  ➢ Detectors rotate back-and-forth starting from RAO to LPO, and LPO back to RAO
  ➢ Total scan duration is around 12 minutes for 20 back-and-forth rotations with a total of 1280 projections views acquired

• Dedicated cardiac CZT systems can make dynamic SPECT acquisitions for MFR more feasible
DEDICATED SOLID STATE CAMERAS

- Conventional NaI detectors are based on collecting energy and spatial information from scintillation events using a large array of photomultiplier tubes
  ➢ “Indirect Process” → Degrades energy and spatial resolution

- In contrast, solid state detectors (e.g. CZT) use a special arrangement of many small detector elements that produce an “all-or-none” response to the detected photon events
  ➢ “Direct Process” → Superior Energy Resolution (FWHM @ ~ 4–6 %)
  ➢ Improved Spatial Resolution and Contrast
CZT VS CONVENTIONAL CAMERA

Images obtained from Spectrum D-SPECT Cardiac Imaging System Brochure
CZT VS CONVENTIONAL DETECTORS

Improved Spatial Resolution

Improved Energy Resolution

Image obtained from DePuey

Energy Spectrum Data from GE Healthcare
(Image obtained from DePuey)
IMPROVED SPATIAL RESOLUTION AND CONTRAST

Conventional Camera

CZT Camera

Image obtained from Verger et al.®
CZT VS CONVENTIONAL DETECTORS

Images From Farrell

SPECT images from 490 lb patient
EXAMPLE MFR QUANTITATION

Images obtained from Spectrum Dynamic SPECT
http://www.spectrum-dynamics.com/protocols/dynamic-spect
MFR QUANTITATION AND TRIPLE VESSEL DISEASE

Images obtained from Hsu et al.¹⁰
DYNAMIC SPECT AND MFR QUANTITATION SOUNDED VERY PROMISING...

HOWEVER, WHAT DOES THIS MEAN FOR DEPARTMENTS THAT CAN ONLY PERFORM CONVENTIONAL MYOCARDIAL PERFUSION STUDIES?
ONE POSSIBLE ANSWER:

WE NEED TO OPTIMIZE THE DIAGNOSTIC QUALITY OF CONVENTIONAL MYOCARDIAL PERFUSION STUDIES
Study compares PET MPI, SPECT in detecting CAD

Intermountain Medical Center researchers found that PET myocardial perfusion imaging improved diagnosis rates for patients with severe obstructive coronary artery disease and reduced the occurrence of invasive catheterization without severe CAD identification, compared with SPECT scans. The findings, presented at the American College of Cardiology’s annual meeting, also showed better identification of patients requiring revascularization, as well as reduced false positives and increased true positives in severe CAD diagnosis, with PET MPI.

ScienceDaily/News release (3/10)
ACQUISITION CONSIDERATIONS

• Adequate Patient Preparation
  ➢ E.g. – Fasting, Caffeine, Medications

• Optimal Imaging Parameters
  ➢ E.g. – Patient dose, Imaging Time, Resolution Recovery Techniques, Detector Radius

• Patient Positioning
  ➢ E.g. – Supine vs Prone/Upright
OPTIMIZE DETECTOR RADIUS TO IMPROVE SPATIAL RESOLUTION

Image adapted from in DePuey and Siemens Medical Solutions
SUPINE VS PRONE POSITIONING

Images from Goto et al.
PROCESSING CONSIDERATIONS

• Motion Correction – “To correct or not to correct?”
  - Reconstruction Parameters
  - Resolution Recovery Algorithms
  - Post-Reconstruction Filtering

When Should We Use Department Defaults vs Study-Specific Settings?
Example Gated Rest Study acquired with low dose 1-day protocol

OSEM With Resolution Recovery Parameters: 3 Iterations; 16 Subsets 3D Gaussian=1.20 cm)

(Images were reconstructed using Hermes Hybrid Recon™ at BCIT)
Example Gated Rest Study acquired with low dose 1-day protocol

OSEM With Resolution Recovery Parameters:
1 Iterations;
4 Subsets
3D Gaussian=1.20 cm)

Significant Blurring

Insufficient Iterations and Subsets
TOO MANY OSEM ITERATIONS

Example Gated Rest Study acquired with low dose 1-day protocol

OSEM With Resolution Recovery Parameters:
12 Iterations;
16 Subsets
3D Gaussian=1.20 cm)

Very Noisy

Too Many Iterations and Subsets
OSEM & LOW COUNT MPI STUDY

What is the Optimal Image Quality For This Study?

Too Noisy?

Too Smooth?
POST-FILTERING FOR NOISE

Default Post-Filter Parameters:

3D Gaussian FWHM = 1.20 cm

(Images Processed at BCIT using Hermes Hybrid Recon™)
POST-FILTERING FOR NOISE

Insufficient Filtering
Too Noisy

Excessive Filtering
Too Smooth

3D Gaussian FWHM = 0.50 cm

3D Gaussian FWHM = 2.00 cm
GENERAL CONCEPTS FOR PROCESSING LOW COUNT STUDIES

FOR LOW COUNT STUDIES WITH OSEM, WE NEED TO CONSIDER LIMITING THE NUMBER OF ITERATIONS AND SUBSETS TO HELP CONTROL THE OVERALL NOISE IN THE RECONSTRUCTED IMAGES.

APPLYING A POST-FILTER CAN OFTEN HELP REDUCE THE NOISE IN THE RECONSTRUCTED IMAGES.

HOWEVER, OVER-FILTERING or UNDER-FILTERING WILL ULTIMATELY AFFECT THE DIAGNOSTIC QUALITY OF THE RECONSTRUCTED IMAGES.
SUMMARY

• Myocardial flow reserve can be measured using dynamic SPECT acquisitions that are often performed in conjunction with conventional MPI protocols.

• Dynamic SPECT studies are commonly performed using solid state detectors because of their improved imaging performance over conventional NaI cameras.

• When MFR studies are clinically unavailable, it becomes increasingly essential that NM technologists remain diligent at optimizing current MPI protocols to maintain the diagnostic sensitivity of the SPECT MPI study.
REFERENCES


