Dynamic SPECT (CFR)

Dynamic Coronary Flow

<table>
<thead>
<tr>
<th>Region</th>
<th>Str</th>
<th>Rest</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>2.40</td>
<td>2.13</td>
<td>1.12</td>
</tr>
<tr>
<td>LCX</td>
<td>3.05</td>
<td>2.16</td>
<td>1.41</td>
</tr>
<tr>
<td>RCA</td>
<td>1.87</td>
<td>1.20</td>
<td>1.55</td>
</tr>
<tr>
<td>TOT</td>
<td>2.41</td>
<td>1.86</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Perfusion

Stress

Rest
Why Do We Need to Assess Coronary Flow?

The problem with SPECT MPI:
- SPECT myocardial perfusion imaging has relatively high sensitivity but low specificity
- SPECT can underestimate disease extent
  - SPECT interpretation can frequently have equivocal findings
  - Balanced reduction in flow can result in a “normal” looking perfusion study
  - Marked variability in quality of study interpretation

Clinical scenarios where quantification is beneficial:
- Patients with:
  > Multi-vessel CAD
  > Microvascular disease (diabetics, often women, etc)
  > Balanced multi-vessel disease
  > Equivocal perfusion findings

What additional clinical information does coronary flow reserve information provide?
- Provides independent quantitative information about all myocardial territories
- Quantification provides information to help interpret subtle perfusion irregularities
Dynamic SPECT Acquisition
Dynamic Acquisition

The spatial and temporal resolution of D-SPECT allows creation of a video of regional myocardial flow in 3D.

Rebinning, Reconstruct, Quantitation
Why is Coronary Flow Reserve Measurement Different than Perfusion & FFR?

- Standard SPECT MPI assessment is based purely on relative perfusion distribution.

- Coronary flow reserve quantitation measures *integrated* hemodynamic effects of epicardial CAD, diffuse atherosclerosis, vessel remodeling and microvascular dysfunction on myocardial tissue perfusion.

\[
CFR = \frac{MBF_{\text{peak hyperemia}}}{MBF_{\text{rest}}}
\]

Courtesy of Drs. Taqueti and Di Carli, Brigham and Women’s Hospital.
What Do I Need to Perform Dynamic SPECT Acquisition and Processing?
Components

- Will need an injector or syringe infusion pump to ensure a quality bolus injection every time
  
  **Injector basic requirements:**
  - Injection speed: 1 to 2 ml/sec
  - Saline injection: 35cc per injection
  - Single or double syringe (customer decision based on use of Regadenason)

- Dynamic SPECT acquisition and reconstruction software (requires 9 detector system)

- INVIA CFR software license
Why Do We Need an Injector or Syringe Infusion Pump?

• Tight bolus required for time activity curves with clear peak
• Automates the process making it repeatable
• Reproducible
• Reduced exposure
• Double barrel injectors can control stress agent administration
Dynamic SPECT Rest-Stress Protocol

Injection method

Radiopharmaceutical: $^{99m}$Tc-Sestamibi

1. Positioning:
   - 37 MBq (1 mCi)
2. Resting Dynamic Scan:
   - 3.5 MBq/kg (0.09 mCi/kg)
3. Stress Dynamic Scan:
   - 10 MBq/kg (0.27 mCi/kg) or 3x resting dose

Injector

- Automation
- Tight Bolus
- Reproducibility
- Controlled Injected Activity
- Stress Agent Injection

Dynamic Imaging Protocol

37 MBq (1 mCi) → Resting Dose → Stress agent → Stress Dose

- POS 1 min
- Rest dynamic acquisition ~ 6 min
- Delay 25 min
- Resting perfusion scan ~ 8 min*
- POS 0.5 min
- Pharmacologic stress agent infusion
- Stress dynamic acquisition ~ 6 min
- Delay 25 min
- Stress perfusion scan ~ 4 min*

*Perfusion imaging times may differ depending on patient BMI.
Clinical Case Review
Case 1: Perfusion Scan

71yo Male
HT, VSA

Perfusion looks normal

Courtesy of Nihon University, Pr. Matsumoto
Case 1: Dynamic Results

Reserve is normal

<table>
<thead>
<tr>
<th>Region</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>3.59</td>
</tr>
<tr>
<td>LCX</td>
<td>3.33</td>
</tr>
<tr>
<td>RCA</td>
<td>3.62</td>
</tr>
<tr>
<td>TOT</td>
<td>3.55</td>
</tr>
</tbody>
</table>

Global Results

<table>
<thead>
<tr>
<th>Region</th>
<th>MC Str</th>
<th>MC Rest</th>
<th>MC Str</th>
<th>MC Rest</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>70%</td>
<td>75%</td>
<td>2.26</td>
<td>0.66</td>
<td>3.59</td>
</tr>
<tr>
<td>LCX</td>
<td>50%</td>
<td>81%</td>
<td>2.23</td>
<td>0.67</td>
<td>3.33</td>
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<tr>
<td>RCA</td>
<td>68%</td>
<td>68%</td>
<td>1.64</td>
<td>0.45</td>
<td>3.62</td>
</tr>
<tr>
<td>TOT</td>
<td>76%</td>
<td>77%</td>
<td>2.11</td>
<td>0.40</td>
<td>3.55</td>
</tr>
</tbody>
</table>

Algorithm (MC Str): To-99m ROIR rest Leppo 1.1m
Algorithm (MC Rest): To-99m ROIR rest Leppo 3m

Courtesy of Nihon University, Pr. Matsumoto
Case 1

- 71y old male with a history of Hypertension, (HT) and Vasospastic Angina (VSA)
- Myocardial Perfusion SPECT appears normal
- Myocardial Blood Flow Reserve looks normal in all main coronary territories
- There is no evidence of organic coronary stenosis. The patient’s angina complaints are relates to coronary spasm episodes.
Case 2: Perfusion Scan

74yo Male
HT, DM, DLP

Perfusion looks normal

Courtesy of Nihon University, Pr. Matsumoto
Case 2: Dynamic Results

Reserve is abnormal
Case 2: Calcium Score

CCS = 5800
Extensive evidence of CAD

Courtesy of Nihon University, Pr. Matsumoto
Case 2

- 74 y old male patient with a history of Hypertension, Diabetes Mellitus, Dyslipoproteinemia
- Myocardial Perfusion SPECT: no evidence of Coronary Ischemia
- Myocardial Blood Flow Reserve is severely diminished in all main coronary territories
- Coronary Angiography shows diffuse Coronary Artery disease in all main coronary branches. Coronary Calcium Score indicates extensive coronary plaque amount >90% of coronary obstruction
Case 3: WD002 Perfusion Scan

70yo, male
Smoker, Known CAD, Prior cx stent
Angina

Courtesy of CHU Caen, Pr Agostini
Case 3: WD002 Dynamic Results

LAD reserve is abnormal

<table>
<thead>
<tr>
<th>Region</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>1.52</td>
</tr>
<tr>
<td>LCX</td>
<td>3.85</td>
</tr>
<tr>
<td>RCA</td>
<td>2.29</td>
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<tr>
<td>TOT</td>
<td>2.31</td>
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Global Results

<table>
<thead>
<tr>
<th>Region</th>
<th>Mean MC Str</th>
<th>Mean MC Rat</th>
<th>Flow (ml/min/g)</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>52 %</td>
<td>70 %</td>
<td>1.20</td>
<td>0.79</td>
</tr>
<tr>
<td>LCX</td>
<td>84 %</td>
<td>89 %</td>
<td>2.97</td>
<td>0.72</td>
</tr>
<tr>
<td>RCA</td>
<td>49 %</td>
<td>52 %</td>
<td>1.58</td>
<td>0.58</td>
</tr>
<tr>
<td>TOT</td>
<td>58 %</td>
<td>65 %</td>
<td>1.64</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Algorithm (MC Str): MEB ROI NetRel Leppo
Algorithm (MC Rat): MEB ROI NetRel Leppo

Courtesy of CHU Caen, Pr Agostini
Case 3: WD002 PET Dynamic Results

Global Results

<table>
<thead>
<tr>
<th>Region</th>
<th>Mean</th>
<th>Reserve</th>
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<tbody>
<tr>
<td></td>
<td>Str</td>
<td>Est</td>
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<tr>
<td>LAD</td>
<td>70%</td>
<td>83%</td>
</tr>
<tr>
<td>LCX</td>
<td>85%</td>
<td>76%</td>
</tr>
<tr>
<td>RCA</td>
<td>89%</td>
<td>81%</td>
</tr>
<tr>
<td>TOT</td>
<td>78%</td>
<td>82%</td>
</tr>
</tbody>
</table>

Region Reserve
LAD 1.41
LCX 2.94
RCA 2.97
TOT 2.32

LAD reserve is abnormal

Courtesy of CHU Caen, Pr Agostini
### Case 3: WD002 Angiography

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Stenosis</th>
<th>FFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>80%</td>
<td>0.47</td>
</tr>
<tr>
<td>LCX</td>
<td>50%</td>
<td>0.98</td>
</tr>
<tr>
<td>RCA</td>
<td>80%</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Courtesy of CHU Caen, Pr Agostini
Case 3

- 70 y old male patient, smoker, with known Coronary Artery Disease, with stent dilatation of Left Circumflex Artery, currently with Angina Pectoris
- Myocardial Perfusion SPECT shows fixed infero-septal perfusion defect and only small amount of reversible ischemia in the antero-septal wall
- Myocardial Blood Flow Reserve is markedly reduced in the LAD territory (far more prominent then in the standard SPECT) and borderline reduced flow reserve in the RCA
- Myocardial Dynamic PET shows similar results
- Both Coronary Angiography and the Fractional Flow Reserve show severe LAD stenosis and RCA stenosis
Case 4: WD008 Perfusion Scan

64yo, female
DM, HT, DLP, Family history Angina, +EE

Courtesy of CHU Caen, Pr Agostini
Case 4: WD008 Dynamic Results

Reserve is abnormal

Algorithm (MC Str): Tc-99m ROI NetRet Leppo 11
Algorithm (MC Rat): Tc-99m ROI NetRet Leppo 11

Global Results

<table>
<thead>
<tr>
<th>Region</th>
<th>MC Str %</th>
<th>MC Rat %</th>
<th>Flow (ml/min/g) MC Str</th>
<th>Flow (ml/min/g) MC Rat</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>82 %</td>
<td>81 %</td>
<td>2.10</td>
<td>1.41</td>
<td>1.49</td>
</tr>
<tr>
<td>LCX</td>
<td>69 %</td>
<td>74 %</td>
<td>1.28</td>
<td>1.13</td>
<td>1.13</td>
</tr>
<tr>
<td>RCA</td>
<td>76 %</td>
<td>77 %</td>
<td>1.62</td>
<td>1.28</td>
<td>1.27</td>
</tr>
<tr>
<td>TOT</td>
<td>78 %</td>
<td>78 %</td>
<td>1.74</td>
<td>1.30</td>
<td>1.34</td>
</tr>
</tbody>
</table>

Reserve

LAD: 1.49
LCX: 1.13
RCA: 1.27
TOT: 1.34

Courtesy of CHU Caen, Pr Agostini
Case 4: WD008 PET Dynamic Results

Reserve is abnormal

Reserve is abnormal

Global Results

<table>
<thead>
<tr>
<th>Region</th>
<th>SE</th>
<th>Rat</th>
<th>Flow (nl/min/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>74 %</td>
<td>79 %</td>
<td>2.62</td>
</tr>
<tr>
<td>LCX</td>
<td>77 %</td>
<td>85 %</td>
<td>2.01</td>
</tr>
<tr>
<td>RCA</td>
<td>79 %</td>
<td>84 %</td>
<td>1.50</td>
</tr>
<tr>
<td>TOT</td>
<td>74 %</td>
<td>89 %</td>
<td>2.10</td>
</tr>
</tbody>
</table>

Algorithm (Snr): Proteo OHTWD RES 1:1
Algorithm (Res): Proteo OHTWD RES 3:1

Region Reserve
LAD   1.85
LCX   1.40
RCA   1.33
TOT   1.58

Reserve is abnormal

Courtesy of CHU Caen, Pr Agostini
### Case 4: WD008 Angiography

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Stenosis</th>
<th>FFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>80%</td>
<td>0.47</td>
</tr>
<tr>
<td>LCX</td>
<td>60%</td>
<td>0.74</td>
</tr>
<tr>
<td>RCA</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Courtesy of CHU Caen, Pr Agostini
Case 4

- 64 y old female with a history of Diabetes Mellitus, Hypertension, Dyslipidemia, family history of Angina Pectoris, & positive EKG
- Standard Myocardial Perfusion SPECT shows mild reversible ischemia in the distal infero-lateral wall & a questionable small area of ischemia in the distal antero-septal wall
- Myocardial Blood Flow Reserve is markedly reduced in all coronary territories and globally
- This finding is confirmed in Dynamic Myocardial PET
- Coronary Angiography shows extensive three-vessel disease
Case 5: WD13 Perfusion Scan

73yo, male
Smoker
Chemo follow-up
Angina

Courtesy of CHU Caen, Pr Agostini
Case 5: WD13 Dynamic Results

It is normal

Region | Reserve
--- | ---
LAD | 2.36
LCX | 2.57
RCA | 3.05
TOT | 2.59

Courtesy of CHU Caen, Pr Agostini
Case 5: WD13 Angiography

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Stenosis</th>
<th>FFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>60%</td>
<td>0.82</td>
</tr>
<tr>
<td>LCX</td>
<td>0%</td>
<td>1.00</td>
</tr>
<tr>
<td>RCA</td>
<td>0%</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Courtesy of CHU Caen, Pr Agostini
Case 5

- 73 y old male, smoker, chemotherapy follow-up with Angina
- Standard Myocardial Perfusion SPECT doesn’t show reversible ischemia but inferior wall evaluation is hampered by prominent tracer concentration in the colon
- Myocardial Blood Flow Reserve is still in normal range in LAD and LCX (cut-off ~ 2). Dynamic SPECT is less affected as data was acquired early, well before appearance of interfering gastro-intestinal concentrations occur.
- Coronary Angiography shows only moderate LAD stenosis with preserved FFR
Case 6: 971175xxxx Perfusion Scan

77yo, female
Prior MI in inferior wall
Prior stent in RCA#1
Case 6: 971175xxxx Dynamic Results

Reserve is abnormal

Courtesy of Sakakibara, Japan, Pr. Iguchi
Case 6: 971175xxxxx Angiography

Vessel	| Stenosis |
---|---|
Prox LAD	| 50% |
Diagonal	| 75% |
Prox LCX	| 90% |
Prox RCA	| 75% |

Courtesy of Sakakibara, Japan, Pr. Iguchi
Case 6

• 77 y old female with an inferior wall myocardial infarction in the past and stent in RCA first segment
• Standard Myocardial Perfusion SPECT shows small distal inferior wall fixed defect attributable to the known MI and a small fixed antero-septal defect
• Myocardial Blood Flow reserve is severely reduced in all coronary territories
• Coronary Angiography shows severe multi-vessel disease - all 3 coronary territories are involved.
Case 7: 290584xxxx Perfusion Scan

84yo, female
Angina at stress
Mild-moderate Aortic stenosis
Hypertension
Hyperlipidemia
Diabetes

Courtesy of Sakakibara, Japan, Pr. Iguchi
Case 7: 290584xxxx Dynamic Results

LAD reserve is abnormal

<table>
<thead>
<tr>
<th>Region</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>1.88</td>
</tr>
<tr>
<td>LCX</td>
<td>2.13</td>
</tr>
<tr>
<td>RCA</td>
<td>2.48</td>
</tr>
<tr>
<td>TOT</td>
<td>2.10</td>
</tr>
</tbody>
</table>

Global Results

<table>
<thead>
<tr>
<th>Region</th>
<th>MC Str</th>
<th>MC Rat</th>
<th>Flow (ml/min/g)</th>
<th>Reserve</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>85 %</td>
<td>86 %</td>
<td>4.92</td>
<td>1.88</td>
</tr>
<tr>
<td>LCX</td>
<td>77 %</td>
<td>74 %</td>
<td>4.50</td>
<td>2.11</td>
</tr>
<tr>
<td>RCA</td>
<td>82 %</td>
<td>81 %</td>
<td>4.71</td>
<td>2.48</td>
</tr>
<tr>
<td>TOT</td>
<td>82 %</td>
<td>81 %</td>
<td>4.52</td>
<td>2.10</td>
</tr>
</tbody>
</table>

Algorithm (MC Str): MIBI ROI NetSet Leppo
Algorithm (MC Rat): MIBI ROI NetSet Leppo

Courtesy of Sakakibara, Japan, Pr. Iguchi
Case 7: 290584xxxxx Angiography

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid LAD</td>
<td>75%</td>
</tr>
<tr>
<td>Diagonal 1</td>
<td>75%</td>
</tr>
</tbody>
</table>

Courtesy of Sakakibara, Japan, Pr. Iguchi
Case 7

- 84 y old female with a history of effort induced angina, Aortic stenosis (mild-to-moderate), hypertension, hyperlipidemia, & diabetes mellitus
- Standard Myocardial Perfusion SPECT fails to detect any significant regional ischemia
- Myocardial blood flow reserve pathologically reduced in LAD
- Coronary Angiography shows significant stenosis in mid-LAD and its Diagonal branch
Case 8: 573795xxxx Perfusion Scan

72yo, female
Angina at stress
Hypertension
Hyperlipidemia
Diabetes
Case 8: 573795xxxxx Dynamic Results

It is abnormal

Courtesy of Sakakibara, Japan, Pr. Iguchi
Vessel Stenosis

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prox &amp; distal LAD</td>
<td>50%</td>
</tr>
<tr>
<td>Diagonal 1</td>
<td>90%</td>
</tr>
<tr>
<td>Ob. Marginal 1</td>
<td>75%</td>
</tr>
<tr>
<td>Distal RCA</td>
<td>75%</td>
</tr>
<tr>
<td>PDA &amp; AV</td>
<td>90%</td>
</tr>
</tbody>
</table>

Case 8: 573795xxxx Angiography

Courtesy of Sakakibara, Japan, Pr. Iguchi
Case 8

- 72 y old female with history of effort angina, hypertension, diabetes mellitus, and hyperlipidemia
- No evidence of reversible myocardial ischemia on standard myocardial perfusion SPECT (questionable mild antero-septal defect)
- Myocardial Blood Flow Reserve is pathologically reduced in all coronary territories
- Coronary angiography shows multi-vessel disease with numerous stenoses in many coronary artery branches distributed across most of the myocardial regions, summing up to a “balanced” coronary ischemia in which no normal areas remain to contrast with pathological ones
Case 9: 104456 History & Previous Angiography

Female 64 y/o
Asymptomatic
Dyslipidemia
Smoking
Hypertension
Type 2 diabetes

Perfusion (report from another lab)
Anterior silent myocardial ischemia

Angiography: May 2015

19 month later (Dec 2016)
Atypical Chest Pain

Referred for:
Perfusion and CFR evaluation with D-SPECT

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prox -Mid LAD</td>
<td>Moderate</td>
</tr>
<tr>
<td>Mid LCX</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
Case 9: 104456 D-SPECT Perfusion Scan

64 y/o Female
63 inches
205 pounds
BMI: 36

Dyslipidemia,
Hypertension,
T2D, Dyslipidemia
& Smoker

Reversible
perfusion defects
in anterior and
inferior wall.
Tissue attenuation
defects due to
BMI?

Courtesy Instituto Cardiovascular de Buenos Aires Argentina, Dr. Meretta
Global and regional reserve are normal.

PTCA or CABG were deferred

Patient continues on Medical treatment
Case 9: 104456

- 64 y/o Female with a history of Dyslipidemia, Hypertension, T2D, Dyslipidemia & Smoker
  - Previous MPI scan showed Anterior Silent Myocardial ischemia
  - Angiography May, 2015

- Dec., 2016- Atypical Chest Pain
- D-SPECT Results
  - Perfusion: Attenuation seen in both Upright & Supine images
    Dynamic: Global & Regional reserves are normal
- PTCA & CABG were deferred; Pt continues on Medical Treatment

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prox-Mid LAD</td>
<td>moderate</td>
</tr>
<tr>
<td>Mid LCX</td>
<td>moderate</td>
</tr>
</tbody>
</table>