Measuring FFR: Fundamentals, Tips and Tricks

William F. Fearon, M.D.
Assistant Professor
Division of Cardiovascular Medicine
Stanford University Medical Center
Derivation of FFR

• FFR = \frac{\text{Myocardial Flow (Stenosis)}}{\text{Myocardial Flow (Normal)}}

• Flow = \frac{\text{Pressure}}{\text{Resistance}}

• \text{at maximal hyperemia} \quad \text{Flow} \approx \text{Pressure}
Derivation of FFR

- FFR = \frac{\text{Coronary Pressure (Stenosis)}}{\text{Coronary Pressure (Normal)}}

- Flow = \frac{\text{Pressure}}{\text{Resistance}}

- at maximal hyperemia \quad \text{Flow} \approx \text{Pressure}
Fractional Flow Reserve

\[ \text{FFR} = \frac{P_d}{P_a} \]

during maximal flow
- Clearly defined normal value
- Not affected by resting hemodynamics
- Relatively easy to perform

Adapted from: Pijls and De Bruyne, Coronary Pressure
FFR in Intermediate Lesions

FFR < 0.75: Sensitivity = 88%
Specificity = 100%

FFR and the “Grey Zone”

FFR and the “Grey Zone”

FFR for decision-making in the cath lab

1.0

0.94

0.90

Interventional use

“Grey Zone”

0.75

Diagnostic use

Based on the teaching file of Paul G. Yock MD, Stanford University.

Note: The specificity of this cut-off value is 100% and the sensitivity is 88%.

References:
Cardiac Death and MI After 5 Years


- FFR ≥ 0.75
  - DEFER: 3.3
  - PERFORM: 7.9
  - P = 0.20

- FFR < 0.75
  - REFERENCE: 15.7
  - P < 0.003
  - P < 0.005

Danger of Deferring PCI if FFR < 0.75

97 patients with intermediate lesions and normal nuclear scans

Chamuleau et al. Am J Cardiol 2002;89:377-380
FFR-Guided PCI vs. Angio-Guided PCI in Multivessel CAD

Results of the FAME study:
1. Improved outcomes
2. Decreased cost
3. Less contrast use
4. Similar procedure time

- Improved outcomes: $6,007 vs $5,332, p<0.001
- Decreased cost: 302 ml vs 272 ml, p<0.001
- Less contrast use: 70 min vs 71 min, p=0.51

Pitfalls / Tips & Tricks

- Inadequate hyperemia
- Pressure drift
- Guide catheter / wire issues
- Particular patient subsets
- Incorporating physiology into your practice
Potential Pitfalls

- Inadequate hyperemia
  - Intracoronary adenosine
    - Short-lasting peak effect (~5 seconds)
    - Don’t use a guiding catheter with sideholes
    - If one suspects inadequate hyperemia, then increase dose (>100 micrograms) or use intravenous adenosine
Potential Pitfalls

• Inadequate hyperemia
  – Intravenous adenosine
    • Should be administered via central vein
    • May require higher doses (>140 ug/kg/min) if given peripherally to avoid metabolism
Performing FFR

Pressure Pullback

Focal LAD Lesion

Proximal Edge of LAD lesion

Distal LAD
Performing FFR

Pullback in Moderately and Diffusely Diseased LAD

Distal → Proximal
Potential Pitfalls

• Inadequate hyperemia
  – Intracoronary Papaverine
    • Peak lasts 30-60 seconds, allowing pullback
    • Transient QT prolongation, T wave changes
    • Rarely causes VT / Torsade de Pointes
Papaverine-Induced Arrhythmia

Papaverine bolus
Potential Pitfalls

- Inadequate hyperemia
  - Caffeine
    - Competitive inhibitor of the adenosine A2a receptor
    - Small studies have shown that caffeine may decrease the sensitivity of dipyridamole stress tests
    - Dipyridamole indirectly increases endogenous adenosine by blocking the cellular reuptake mechanism
Caffeine and FFR

FFR measured with 30-50 ugs of IC adenosine before and after 2-3 “cups” of coffee

Pitfalls / Tips & Tricks

• Inadequate hyperemia
• Pressure drift
• Guide catheter / wire issues
• Particular patient subsets
• Incorporating physiology into your practice
Potential Pitfalls

Recognizing True Pressure Drift

Potential Pitfalls

• Pressure Drift
  – Causes of artifactual drift
    • Wire introducer
    • Paradoxical gradient
    • Contrast in guide catheter
Pitfalls / Tips & Tricks

• Inadequate hyperemia
• Pressure drift
• Guide catheter / wire issues
• Particular patient subsets
• Incorporating physiology into your practice
FFR of the LAD...
Is this correct?
Deep-Seated Guide Resulting in Ventricularization

59 Pa mean
49 Pd mean
0.83 FFR

28.5 CURSOR
Unseating of Guide Catheter Reveals True FFR
Wiring Tortuous Vessels

Consider disconnecting the wire from the interface connector.

Can use exchange catheter to more safely position the pressure wire.
Pitfalls / Tips & Tricks

- Inadequate hyperemia
- Pressure drift
- Guide catheter / wire issues
- Particular patient subsets
- Incorporating physiology into your practice
Potential Pitfalls

• Particular patient subsets
  – LVH
    • ↑↑ muscle mass compared to vasculature
    • FFR cuttoff value may be higher than 0.75
  – Exercise-induced vasoconstriction
    • Greater stenosis with exercise compared to adenosine
FFR during STEMI
FFR during STEMI
FFR during STEMI

IMR = Pressure / Flow = 78 / (1/1.22) = 95
Acute Microvascular Damage and FFR

STEMI

Variable Degree of Reversible Microvascular Stunning

Maximum Achievable Flow is Less

With time, the microvasculature may recover, maximum achievable flow may increase, and a larger gradient with a lower FFR may be measured across a given stenosis

Smaller Gradient and Higher FFR across Any Given Stenosis
FFR in Chronic MI

67 yo man 9 months after STEMI and PCI of Cx
FFR in Chronic MI

FFR of Left Circumflex

Resting IV Adenosine

75 Pa mean
70 Pd mean
0.94 FFR

29.0 CURSOR

Stanford
Chronic Microvascular Damage and FFR

Old Myocardial Infarction  
Irreversible Microvascular Damage

In the setting of chronic microvascular dysfunction, the higher FFR is not falsely elevated, but reflects the smaller amount of viable myocardium supplied by the vessel and still provides information about the expected gain in flow after PCI.

Maximum Achievable Flow is Less

Smaller Gradient and Higher FFR across Any Given Stenosis
FFR in Chronic MI

Comparison of FFR in 57 patients with an MI ≥ 6 days old to SPECT imaging before and after PCI

Comparison of MACE in FAME patients with and without ACS
Incorporating Physiology
Incorporating Physiology

- Educating your assistants
  - Limitations of angiography
  - Benefits of physiology
  - Measure FFR in 10 consecutive PCI cases

- Streamlining set-up
  - Identify point person
  - Post medication mixing and dosing instructions
  - Keep analyzer connected at all times