FFR: Tips and Tricks

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Disclosures

• Abbott Vascular: Speaker, Proctor (MitraClip)
• Boston Scientific: Consultant, honorarium
• Philips: Honorarium
• Medtronic: Research support
• St Jude Medical: Speaker, honorarium
Standardization of Fractional Flow Reserve Measurements

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Clinical pitfalls

• Reassessing borderline lesions in symptomatic patients with documented ischemia on stress scans in appropriate territory
• Not trusting FFR results after achieving a negative result
FFR in the presence of a stenosis

\[ P_d < P_a \]

\[ FFR_{myo} = \frac{P_d}{P_a} < 1 \]
Significant or not?

Significant

NOT significant

0 0.75 0.80 1.0

FFR < 0.75 → always ischemia (specificity 100%)
FFR > 0.75 → ischemia very unlikely (sensitivity 88%)

“Measurement of Fractional Flow Reserve to assess the Functional Severity of Coronary Artery Stenoses”,
Pijls et al; The New England Journal of Medicine;
FFR interactions

• Epicardial stenosis severity
• Extent of perfusion territory
• Myocardial blood flow
• Inducible ischemia
FFR
- takes into account the size of perfusion area

FFR = 0.60

Large perfusion area

FFR = 0.85

Small perfusion area
FFR
- takes into account the size of perfusion area

FFR = 0.60

FFR = 0.80
FFR
- takes into account the contribution of collaterals

FFR = 0.70

Poorly developed collaterals

100 → 70

P_a → P_d → P_v
FFR
- takes into account the contribution of collaterals

Well developed collaterals

$P_a \rightarrow 100 \rightarrow P_d \rightarrow 85 \rightarrow P_v \rightarrow 0$

$FFR = 0.85$
FFR
- takes into account the of blood pressure changes
Technical pitfalls

• Insufficient hyperemia
• Guide catheter:
  – Deep engagement or disengagement
  – Directed towards LCX or LAD in short left main
    Guides with side holes
• Ensuring appropriate zeroing of table height
  before introducing the pressure wire
Transducer Height

- Position the transducer at the correct height (in level with the aortic root) before beginning the procedure.
- To keep pressure measurements accurate, do not move the transducer during the procedure.
Importance of the appropriate transducer height

Pressure TOO LOW

Pressure TOO HIGH
Importance of Maximum Hyperemia

MAXIMUM HYPEREMIA IS OF PARAMOUNT IMPORTANCE:

- Insufficient hyperemia
  - Underestimation of gradient
    - Overestimation of FFR
      - Underestimation of stenosis severity
Suboptimal Maximal Hyperemia

- Suboptimal hyperemia commonly occurs when a drug is administered via a peripheral vein or when the patient holds his breath causing Valsalva effect.
Steady State Maximum Hyperemia

- Use an IV stimulus via a femoral sheath to achieve steady state hyperemia.
- The Mean Pd/Pa line is only seen during recording.
- Look for a smooth, nonfluctuating line.
Wedging of the Guiding Catheter:
large guiding can cause insufficient hyperemia

7 F Guiding Catheter

3 mm RCA

50% Area Stenosis
FIGURE 2  Effect of Guiding Catheters in Different Coronary Ostia

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>20% DS</th>
<th>30% DS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-F</td>
<td>17%</td>
<td>27%</td>
<td>39%</td>
</tr>
<tr>
<td>6-F</td>
<td>25%</td>
<td>39%</td>
<td>56%</td>
</tr>
<tr>
<td>7-F</td>
<td>34%</td>
<td>52%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Presence of a guiding catheter in the coronary ostium can significantly impede coronary blood flow. The figure illustrates the potential area obstruction (values in red) of different sizes of guiding catheters (5- to 7-F from the first to the last row) in a 4-mm coronary ostium when it is intact (left), when it is 20% stenosed (middle), and when it is 30% stenosed (right).
FFR in the case of diseased coronary ostium

- Use IV adenosine
- Dislodge guiding during measurement
- 5F guides, ensure no pressure dampening on engagement
- Guiders with side holes precludes IC stimulus for hyperemia due to unreliable aortic pressure recording by the side holes
PressureWire in LAD and guiding catheter disengaged. IV adenosine
Maximal hyperemic pressure pullback

(IV adenosine, guider out of ostium)
Deep-Seated Guide Resulting in Ventricularization
Unseating of Guide Catheter Reveals True FFR
Deep-Seated Guiding Catheter

- A deep-seated catheter in the ostium of the right or left main arteries can cause damping of the aortic waveform.
- Waveform 1 shows damping with the catheter inserted.
- Waveform 2 shows the effect when the catheter is withdrawn into the aorta revealing an immediate pressure gradient.
Equalization

- Equalization between aortic and sensor pressures must always take place with the sensor just outside the tip of the guide catheter.
- Same for equalization of left main lesions, but with the guide catheter withdrawn into the aorta or with the sensor tip just inside the guide catheter.
- Validate equal pressures at the end of each procedure to confirm that drift has not occurred.
Coronary Pressure: RECOGNIZING DRIFT

Trans-stenotic pressure

Rest:
- Predominantly diastolic gradient
- Small or no systolic gradient

Hyperemia:
- Increase of diastolic gradient
- Also some systolic gradient

Recognizing drift: Parallel signals with equal gradient throughout both diastole and systole
Drift Waveforms

- Drift significantly affects FFR.
- Curves that are identical during maximum hyperemia, especially when a gradient exists, may be drift.
- Always verify equal pressures at the end of each procedure.
How to recognize drift?

1. Parallel signals with equal gradient in systole and diastole
2. Aortic notch still present despite large pressure difference
Drift: morphology of the pressure tracings is identical.

Pressure gradient: morphology of the pressure tracings is different.
Common pitfalls: RECOGNIZING DRIFT

**IF IN DOUBT:**

- Go back to tip of guiding catheter and re-equalize
- Pressure-pull back curve correction.

This is an acceptable method at the end of the procedure but more steps
**Introducer Needle**

- A needle may cause flowback and result in a lowering of aortic pressure reading.

- Remove the needle and close the hemostatic valve during equalization and when measuring FFR.

- The hemostatic valve may be relaxed slightly during pullback.
Tandem stenoses: IV Adenosine

- Place the wire distally
- Induce hyperemia (IV adenosine) and determine FFR. If FFR < 0.75 – 0.80, inducible ischemia related to this artery is established and PCI is appropriate.
- Start the pull-back recording under fluoroscopy and establish those spots or segments with a sudden pressure drop.
- If local pressure drops ≥ 10 mmHg are present, stenting of those spots can be considered.
- The “most severe” spot is stented first
- Repeat pull-back recording
FFR in tandem stenoses

- Rule of thumb: a severe distal lesion can mask the gradient across a proximal lesion much more than vice versa
- Check again
- Stenting segments with gradient < 10 mm not indicated
- Diffuse disease: gradual decline of pressure along the artery (diffuse disease)
FFR in ACS

• If not clear, use FFR
FFR with wire bias

- Pseudo-lesions created by wire bias esp in tortuous vessels
- FFR can be inaccurate
- Difficult to quantify degree of effect
- Coronary vasospasm can affect FFR: Give IC GTN
FFR in Myocardial bridging

Adenosine i.c

EKG

Pressure (mm Hg)

Instantaneous pressure gradient (mm Hg)

Adenosine i.c. + dobutamine i.v

EKG

Pressure (mm Hg)

Instantaneous pressure gradient (mm Hg)
Drugs
**TABLE 1  Hyperemic Stimuli**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dosage</th>
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<tbody>
<tr>
<td>Adenosine</td>
<td>100 μg in RCA/200 μg in LCA as intracoronary bolus</td>
</tr>
<tr>
<td>Nitroprusside</td>
<td>140 μg/kg/min as intravenous infusion</td>
</tr>
<tr>
<td></td>
<td>0.6 μg/kg as intracoronary bolus</td>
</tr>
<tr>
<td>Nicorandil</td>
<td>2 mg as intracoronary bolus</td>
</tr>
<tr>
<td>Regadenoson</td>
<td>400 μg as intravenous slow bolus over 10 s</td>
</tr>
<tr>
<td>Papaverine</td>
<td>8 mg in RCA/12 mg in LCA as intracoronary bolus</td>
</tr>
</tbody>
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LCA = left coronary artery; RCA = right coronary artery.
Intravenous Adenosine
# Intracoronary Adenosine

<table>
<thead>
<tr>
<th>Guide catheters with side holes may</th>
<th>Unknown amounts of the drug may spill into the aorta.</th>
</tr>
</thead>
<tbody>
<tr>
<td>should NOT be used.</td>
<td></td>
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<table>
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<th>Guide catheters that are too large (tight) for the ostium should NOT be used.</th>
<th>Pressure dampening may occur.</th>
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<td></td>
<td>This can be recognized by a culized aortic pressure curve.</td>
</tr>
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<table>
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<tr>
<th>NO pullback curve is possible</th>
<th>No steady-state hyperemia</th>
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<tr>
<th>Interruption of blood pressure (Pa) should be as short as possible.</th>
<th>If too long, hyperemia will be over before aortic pressure can be measured</th>
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Intracoronary Papaverine

EFFECTS:
Peak effect: 10-30 seconds after administration
Duration effect: 45-60 seconds

SIDE EFFECTS
QT-prolongation and T-wave changes. Transient
Torsades des pointes Rare
Ventricular Tachycardia
Ventricular Fibrillation
### Intracoronary Papaverine

<table>
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<tr>
<th>Pullback curve possible</th>
<th>Steady-state hypermia</th>
</tr>
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<tr>
<th>Do NOT use ionic contrast agents (e.g. Hexabrix)</th>
<th>Crystalization effect.</th>
</tr>
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<thead>
<tr>
<th>Avoid use together with drugs that cause QT prolongation. Women and patients with bradycardia have greater risk for torsades</th>
<th>Increased risk for side effects in these cases.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wait 5 minutes between successive measurements. Limit number of given doses to max. 3</td>
<td>Reduce the risk for side effects.</td>
</tr>
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DIAGNOSING LESION SEVERITY VIA CONTRAST FFR†

- Increased blood flow unmask lesion severity and increases diagnostic accuracy
- IC-delivered contrast provides a hyperemic effect ~60% equivalent to adenosine
- Contrast FFR is an alternative to adenosine to obtain hyperemia, if adenosine is considered time-consuming, expensive, and burdensome
- Contrast FFR is easy, inexpensive and safe, and displays excellent test/retest stability

Measure (Single Cutoff) | Accuracy vs. FFR
---|---
Contrast FFR ≤ 0.83 | 85.5%
iFR™ ≤ 0.90 | 79.6%
Pd/Pa ≤ 0.92 | 78.4%

Contrast FFR has superior accuracy vs. resting indices (p<0.001)
Summary

- Know mechanism of FFR
- Know different drugs
- Ostial LM/RCA considerations
- Drift
- Tandem lesions: pull back, IV adenosine
- Remember to check pull back ratio