Physiologic Assessment of Coronary Artery

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Concept of FFR related to pressure measurements
Prognostic significance of reversible ischemia at MIBI-Spect

Iskander S et al, JACC 1998
Non-Invasive Stress Testing and PCI

Exercise Test Performed Before Angioplasty

71%

29%

NO Exercise Test Performed Before Angioplasty

Topol et al. Circulation 1993
Conceptual limitations of non-invasive testing:

- **Diagnostic accuracy not optimal**, especially not in intermediate stenosis

- **Limited spatial resolution**, especially in patients with more complex disease (unfortunately quite common nowadays):
  - multivessel disease
  - several stenoses within the same artery
  - uncertainty about exact perfusion territories

- No discrimination between **epicardial vs microvascular disease** or **local stenosis vs diffuse epicardial disease**
**Practical reasons why non-invasive testing is often not performed:**

- Needs to be performed in *another department* (MIBI-Spect)
- *Patient is already on the table* for diagnostic angiography and the interventionalist wants to proceed immediately
- Increasing numbers of *acute patients* in the cathlab (with often multiple lesions)
- *Financial considerations, shortening of hospital stay*
Assessing Stenosis Severity in the Catheterization Laboratory

Quantitative Coronary Angiography

Limitations

- applicable in only a minority of stenoses
- reference segment = normal
- not all dimensions taken into account
- physiologic parameters not taken into account
- collaterals not taken into account

Not very helpful for clinical decision making.
FFR (Myocardial Fractional Flow Reserve): a Flow Index Derived from Pressures

\[
\frac{Q^S_{\text{max}}}{P_N} = \frac{Q_{\text{max}}}{P_N} = \text{FFR}
\]

\[
\text{FFR} = \frac{(P_d - P_v)}{R_{\text{myo}}} = \frac{P_d}{P_a}
\]

\[
\frac{(P_a - P_v)}{R_{\text{myo}}}
\]
Fractional Flow Reserve in Clinical Practice

**Adenosine IC**

**REST**

- Proximal to the lesion
- Crossing the lesion
- Distal to the lesion

**HYPEREMIA**

- FFR = 58/112 = 0.52
Normal Value of FFR

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

Normal FFR = 1
Ischemic FFR = 0.75
 Coronary Pressure Measurements

Prerequisites

1. Pressure Measuring Guide Wire
2. Maximal Hyperemia
3. FFR instead of $\Delta P$
Pressure Monitoring Guide Wire

0.014"

3 cm
Pressure Monitoring Guide Wire

$P_a = \text{Guiding Catheter}$

$P_d = \text{Pressure Wire}$
Hyperemia - administration

• Hyperemic stimuli
  – Intravenous Adenosine  140-160 µg/kg/min
  – Intracoronary Adenosine LCA: 20-40 µg
    RCA: 15-30 µg
  – Intracoronary Adenosine Infusion
Influence of Systemic Pressure on Trans-stenotic Gradient

- **Aortic Pressure = 122 mm Hg**
  - \( \Delta P = 70 \text{ mmHg} \)
  - FFR = 52/122 = 0.43

- **Aortic Pressure = 89 mm Hg**
  - \( \Delta P = 49 \text{ mmHg} \)
  - FFR = 40/89 = 0.45

- **Coronary Pressure = 52 mm Hg**
- **Coronary Pressure = 40 mm Hg**
FFR: Unique Features

**FFR**$_{myo}$ ...

is a lesion specific index

is independent of hemodynamic parameters

has a normal value of 1.0

takes into account collateral flow

has no need for a normal control artery

can be easily obtained: $\text{FFR}_{myo} = \frac{P_d}{P_a}$
Pitfalls related to pressure measurements
Pitfalls, The "Height effect"

- The proximal pressure is normally measured through the liquid column in a guiding catheter.
  - External pressure sensor must be fixed level with the heart.

- 13 mm difference in height (h) will produce an error of 1 mm Hg.

- Place the sensor close to the tip of the guide catheter.
- Adjust the height of the external pressure transducer, until signals are equal.

Importance of the Height of the Transducer

Transducer of the Fluid-Filled Guiding Catheter

Lifted UP DOWN
Pressure leakage through RHV / Guidewire Introducer

Cause

Minimal leakage from RHV = pressure loss from guiding catheter (typically 5-8 mmHg)

Can occur if RHV is tightened with g.w. introducer still in place

Effect

Pa under-estimated

FFR over-estimated
Recommendations, Guiding Catheter Size

Diagnostic case: 6 F or 7 F
Interventional case: 7 F

Too small
damped aortic signal through the guiding catheter

Too big
partial occlusion/restriction of coronary blood flow
FFR and Guidings with Side-Holes

When wedging of the catheter, withdraw guiding from ostium

For flow or pressure measurements:
NO SIDE-HOLES
Guiding Catheter With Sides Holes

Sensor proximal to side holes
Guiding Catheter With Sides Holes

Sensor in the proximal RCA
Guiding Catheter With Sides Holes

Sensor in the proximal RCA + Papaverine
Guiding Catheters with Sideholes

If it is essential ...

- Beware of signal misinterpretation
- Withdraw guiding catheter from ostium during measurements
- Do not use i.c. hyperemic stimulus

Use i.v. hyperemia stimulus and withdraw the guiding catheter from the ostium during measurement.
Choice of hyperemic stimuli

**Intra coronary**
- Guiding catheter position
- Guiding catheter side-holes
- Too quick (3rd pressure line)

**Intra venous**
- Femoral vein only
- High volume infusion pump
Intracoronary Bolus of Adenosine

time-to-peak: 15”
Plateau: 8”
Total duration: 25”

Dosages:

LCA: 20-40 µg
RCA: 15-30 µg
Intravenous Infusion of Adenosine 140 µg/kg/min
Intravenous Infusion of Adenosine

Pull-back Curve

Slow pull-back of sensor across stenosis during steady state maximum hyperemia

Most reliable and reproducible way to determine exactly the physiologic significance

Reproducible, without withdrawing the wire from the stenosis

(only the sensor moves across the lesion, the tip of the wire remain distally)
Example of Pullback Curve

Pull-back curve at maximum hyperemia (i.v. adenosine infusion)

distal stenosis proximal stenosis
Wedging of the Guiding Catheter: Importance of Flow

7 F Guiding Catheter

3 mm RCA

50% Area Stenosis
Influence of the Guiding in the Ostium

FFR = 63 / 88 = 0.71

Guiding = Disengaged
Influence of the Guiding in the Ostium

Guiding Catheter

Femoral Artery

Distal Coronary Artery

Rest

Hyperemia

Guiding = Engaged into Ostium

$\text{FFR} = \frac{63}{81} = 0.78$
Drift of the Pressure Sensor

Drift: morphology of the pressure tracings is **identical**

Pressure Gradient: morphology of the pressure tracings is **different**
Clinical Applications of FFR related to pressure measurements
Clinical Applications
DEFER STUDY

DEFER Study: 2 year Event-free Survival
Event rate per year for non-significant lesion is 5 %

Bech GJ, Circulation 2001; 103 : 2928-34
1. Before PTCA: *Should we dilate?*
   - > 0.75: NO
   - < 0.75: YES

2. After balloon angioplasty: *Is this result sufficient?*
   - < 0.90: NO
   - ≥ 0.90: YES

3. After stenting: *Is the stent well deployed?*
   - < 0.94: NO
   - ≥ 0.94: YES
Coronary Pressure Measurement in Complex PCI

This means:

Detailed **spatial and segmental information** on the functional impact of the disease is paramount for **optimum benefit of PCI**:

- Which of several arteries are culprit?
- Selection of culprit spots and segments within a unparticular artery
- Is it focal epicardial or diffuse or microvascular disease that causes the ischemia

Coronary Pressure Measurement
## Clinical Implication of FFR

<table>
<thead>
<tr>
<th></th>
<th>IVUS</th>
<th>FFR</th>
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<tbody>
<tr>
<td>Native CAD</td>
<td>MLD ≥1.8 mm</td>
<td>≥0.75–0.8</td>
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<tr>
<td></td>
<td>MLA ≥4.0 mm²</td>
<td></td>
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<tr>
<td>Left main</td>
<td>MLD ≥2.8 mm</td>
<td>≥0.75</td>
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<tr>
<td></td>
<td>MLA ≥5.9 mm²</td>
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<td>Serial lesions</td>
<td>Assesses anatomic severity along the length of the artery</td>
<td>Relative contribution of each stenosis on pullback method</td>
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<tr>
<td>SVG</td>
<td>Identifies severe lesion and tissue characteristics. Helps identify when to use distal protection device</td>
<td>No data for FFR in SVG; data correlating rCFR with SPECT available</td>
</tr>
<tr>
<td>Ostial lesions</td>
<td>Helps locate ostial-aorta juncture and correct stent position</td>
<td>≥0.75</td>
</tr>
<tr>
<td>Acute MI</td>
<td>Demonstrates plaque burden</td>
<td>Limited data</td>
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<tr>
<td>Bifurcation lesions</td>
<td>Assesses size of main and side branch, adequacy of results</td>
<td>≥0.75</td>
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Conclusion

1. FFR can be measured **successfully** in most cases and **extremely reproducible**.

2. FFR < 0.75 always indicates inducible ischemia and >0.80 excludes ischemia in 91% of the cases - FFR assessment can be used direct PCI only ischemic, flow-limiting lesions.

3. FFR has a **prognostic value** in post-stenting and normalization of FFR after stenting was accompanied by a restenosis rate of <5% at six-month follow up.

4. FFR can be useful in **more complex and extensive coronary disease**.