CORONARY PHYSIOLOGY IN THE CATHLAB:

FFR POST - PCI

Educational Training Program ESC
European Heart House
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Do we have systematic data?

only a few good studies

Because the extreme heterogeneity of patients (inherent to the nature of coronary artery disease) there does not exist one single “uniform” FFR post-stent value indicative for a good result.

Nevertheless, FFR post-stent can give very useful information, if measured and interpreted in the right way.
Hanekamp et al.; Circulation 1999;99:1015-1024

ROC curve, showing sensitivity and specificity for several FFR cut-off values, compared to intravascular ultrasound, for assessment of optimal stent deployment.
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ROC curve, showing sensitivity and specificity for several FFR cut-off values, compared to intravascular ultrasound, for assessment of optimal stent deployment.

$\text{FFR} \leq 0.88 \rightarrow \text{IVUS always abnormal}$
FFR post-stent versus IVUS

FFR ≥ 0.95 → IVUS is normal in 95% of cases

Hanekamp et al; Circulation 1999;99:1015-1024
FFR-post-STENT Registry (N = 750)

% ADVERSE EVENTS AT 6 MONTHS

Number of patients

% adverse event at 6 months

Circulation 2002
The Stent –Registry was performed more than 10 years ago, when the extent of disease and atherosclerotic burden in the average patient was much less than today.

It is unknown in the stent Registry, if a persistent gradient was due to focal pressure drop across the stent, or to (focal or diffuse) disease more proximal or distal in the artery.

Events might be promoted by both: by inadequately deployed stents as well as high atherosclerotic burden elsewhere in the artery.
A residual gradient within the coronary artery after apparently successful stenting, can be caused by:

- *inadequate stent deployment (focal gradient across stent)*, or by

- *diffuse disease or other lesions (more proximal or distal) along the course of the stented artery*

The most reliable way to discriminate this, is a hyperemic pullback recording (i.v adenosine, i.c. papaverine, or i.v. regadenoson bolus) after stenting.
FFR post PCI:

HOW SHOULD WE DO IT IN CLINICAL PRACTICE?

Let’s have a look at 3 different patients but all with chest pain and a positive MIBI in the inferior wall.
Typical chest pain; positive MIBI-Spect inferior wall
Typical chest pain; positive MIBI-Spect inferior wall
Very obese male,

Typical chest pain; positive MIBI-Spect inferior wall
PressureWire in RCA
resting → hyperemia (i.v. adenosine)

RCA pullback - advance - etc
resting

hyperemia (i.v. adenosine)

Pd/Pa = 0.99
iFR = 1.00
FFR = 0.54

pullback - advance - etc
RCA after stenting

hyperemia
(adenosine)
Dist. stenose

Mid in-stent restenose

Dist. stenose

Hyperemia: Pull back recording

FFR = 0.65
Dist. Stenosis
after treatment

Prox. stenosis after
treatment

Hyperaemie: sensor in PLRCA

FFR = 116/118 = 0.98
Very obese male,

Typical chest pain; positive MIBI-Spect inferior wall
Hyperemic pull-back recording along the RCA

Fundamentally impossible to treat this patient by stenting
Be aware that after stenting a stenosis, blood flow in the artery will increase and other gradients within the vessel may be unmasked or increase!
RCA:

FFR = 0.34
resting  adenosine  pullback

Pull-back across distal stenosis

58 mmHg

‡ 5 mmHg
RCA after one stent:

FFR = 0.74
FFR 0.34 → 0.74

Resting adenosine pullback

Pullback across stent & across proximal stenosis

58 → ~0 mmHg

5 → 22 mmHg
RCA after 2 stents:

FFR = 0.87

(pullback shows diffuse disease but no gradient across any of the stents)
Pressure sensor back at the ostium of the RCA
What is a “normal” (or “acceptable”) gradient across a well-deployed stent?

• immediately after implantation
• at follow up

Mechanistic study by Van ‘t Veer et al: “Hemodynamic Characteristics of DES at Implantation and at 6-m Follow-up”

Eur Heart J 2006;27:1811-1817
Sirolimus study (Van ‘t Veer et al, Eur Heart J 2006)

- 20 patients
- 2 stenoses
- comparable (diameter / length)
- 1 DES (Cypher)
- 1 ‘normal’ stent (BX Velocity)
- assigned randomly
Sirolimus study (Van ‘t Veer et al, Eur Heart J 2006)

- quantitative coronary angiography (QCA)
  - % diameter (area) stenosis
  - Minimal Luminal Diameter (MLD)
  - Late loss

- Physiologic measurements
  - Pressure
  - Blood flow velocity
  - Wall shear stress

- all measurements repeated after 6 months
FFR and hyperemic Pd/Pa before & immediately after stenting, and at 6-month follow-up

<table>
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<th>Bare metal</th>
<th>P value</th>
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| **Hyperemic pressure ratio across stent** |        |            |         |
| immediately after | 0.97±0.02 | 0.96±0.04  | NS      |
| Follow-up         | 0.99±0.01 | 0.91±0.09  | P<0.01  |

Van ‘t Veer et al, Eur Heart J 2006
Immediately after good stenting, the hyperemic gradient Across the stent is < 5 mmHg

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Van ‘t Veer et al, Eur Heart J 2006
At 6 months, some gradient (approximately 10 mmHg) is present across a BMS stent, but no noticeable gradient across a DES

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Van ‘t Veer et al, Eur Heart J 2006
Stent boost technique

Tanaka et al, Japan Circulation J, 2012: *Stent boost vs FFR post-stenting*

Weak correlation between abnormal stent boost and hyperemic gradient across stent of > 5 mmHG
I. When we use pressure wire for deciding whether or not to stent, we use it as primary guidewire and standardly measure FFR post stenting

II. After angiographically successful stenting, place the sensor in distal third part of the artery (and at least distal to stented lesion(s)) and induce hyperemia for pullback recording:
   - i.v. adenosine infusion, preferably central line
   - i.v. peripheral bolus injection of 400 µg regadenoson

III. Perform manual pullback recording under fluoroscopy: and check if remaining gradient is across stent or else where in the coronary artery, accepting the consequences
If a stent is deployed adequately, only a negligible hyperemic gradient should be present across the stent.

If a hyperemic gradient of > 5 mm Hg persists across the stent, there is most likely a problem and preferably OCT is indicated.

The opposite is not true: even without an hyperemic gradient, a stent can be insufficiently deployed (5% of cases).

Therefore, FFR post-stent cannot replace OCT.
FFR post PCI: CONCLUSIONS (2)

• FFR post PCI is *extremely useful to detect residual lesions or diffuse disease* with direct consequence for further treatment or preventing unnecessary repeat procedures when recurrent chest pain or ischemia occurs.

• The *hyperemic* pressure pullback recording is the most accurate method to analyse the remaining disease along the coronary artery and cannot be replaced by any other technology.

*Caveat...!!...:*

*There might be a psychological barrier for measuring FFR after stenting! Sometimes it indicates merciless that we are not always as good as we wish to be.*
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