FFR in diffuse disease and serial stenoses

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Single stenosis

66 y.o. Female with hypertension and 6 months history of angina.
Single stenosis

- Functional severity of a focal stenosis in an otherwise non-diseased vessel is easily assessed by the ratio between distal and proximal pressure, $P_d / P_a$ during maximum hyperemia (FFR).

- No substantial change in FFR in different positions distal to the stenosis.

- Functional result after PCI is highly predictable.
Serial stenoses

59 y.o. Male with angina CCS 3 and a perfusion scan showing apical/septal reversible perfusion defects.
Serial stenoses

- In the presence of multiple lesions within the same vessel, fluid dynamic interaction between the stenoses complicates the assessment of functional severity.

- The individual contribution of each stenosis to "total" FFR is not easily predicted.

- Complex lesions, if functionally *significant*, may affect the choice of treatment strategy (favouring CABG).

- Complex lesions, if functionally *non-significant*, should be left untouched (favouring PCI in remaining lesions).
Diffuse disease

48 y.o. Male with angina CCS 2 and a positive bicycle stress test.
Diffuse disease

- Diffuse atherosclerotic disease adds further complexity to the assessment of functional severity.

- Flow limitation may be predominantly caused by long diffusely diseased segments despite more conspicuous focal lesions (PCI will not help).

- Significant gradients may exist even in the absence of focal lesions.
Coronary pressure in a normal epicardial vessel

\[ P_a = 100 \text{ mmHg} \]
Coronary pressure in the presence of one focal lesion.
Coronary pressure in the presence of one focal lesion and concomitant diffuse disease.
Coronary pressure in the presence of serial lesions.
Induction of maximum hyperemic flow is a fundamental basis of FFR. A second proximal or diastal stenosis potentially limits maximum flow, thereby changing this prerequisite.

The "apparent" FFR of each stenosis may be expressed as:

- $\text{FFR}(A)_{\text{app}} = \frac{P_m}{P_a}$
- $\text{FFR}(B)_{\text{app}} = \frac{P_d}{P_m}$
The FFR of individual lesions may be *predicted* by applying fluid dynamic theory, incorporating the coronary wedge pressure;

\[
FFR(A)_{pred} = \frac{P_d - \left( \frac{P_m}{P_a} \right) P_w}{P_a - P_m + P_d - P_w}
\]

\[
FFR(B)_{pred} = 1 - \frac{(P_a - P_w)(P_m - P_d)}{P_a(P_m - P_w)}
\]
Pressure-Derived Fractional Flow Reserve to Assess Serial Epicardial Stenoses

Theoretical Basis and Animal Validation

Bernard De Bruyne, MD, PhD; Nico H.J. Pijls, MD, PhD; Guy R. Heyndrickx, MD, PhD; Dominique Hodeige, MD; Richard Kirkeeide, PhD; K. Lance Gould, MD
Open chest dogs, 2 stenoses of varying severity.

\[
\text{FFR}(A)_{\text{pred}} = \frac{P_d - \left(\frac{P_m}{P_a}\right) P_w}{P_a - P_m + P_d - P_w}
\]

\[
\text{FFR}(B)_{\text{pred}} = 1 - \frac{(P_a - P_w)(P_m - P_d)}{P_a (P_m - P_w)}
\]
\( \text{FFR}_{\text{app}} \) and \( \text{FFR}_{\text{pred}} \) vs \( \text{FFR}_{\text{true}} \) in cases of one fixed and one variable stenosis.

Coronary Pressure Measurement to Assess the Hemodynamic Significance of Serial Stenoses Within One Coronary Artery

Validation in Humans

Nico H.J. Pijls, MD, PhD; Bernard De Bruyne, MD, PhD; G. Jan Willem Bech, MD; Francesco Liistro, MD; Guy R. Heyndrickx, MD, PhD; Hans J.R.M. Bonnier, MD, PhD; Jacques J. Koolen, MD, PhD
• 32 patients with ≥ 2 lesions in one vessel
• Pressure pull-back
• PTCA of most severe + wedge pressure
• Re-measure after removal of one stenosis
\[
\frac{P_d - \left( \frac{P_m}{P_a} \right) P_w}{P_a - P_m + P_d - P_w}
\]
Practical approach: the pressure pull-back recording
The pressure pull-back recording

- Continuous infusion of Adenosine 140 μg/kg/min.
- Steady state maximum hyperemia after app. 1 min.
- Chest discomfort / dyspnea (instruct the patient to breathe normally)
- Slight (10-15%) decline in blood pressure
The pressure pull-back recording

- Slow pull-back of the pressure wire during fluoroscopy in order to correlate pressure with anatomy
- Check equalizing position (should be 1,0!)
- Analyze recording
The pressure pull-back recording

- Focal step-up?
- Diffuse disease without focal step-up?
- Combination?
- Clinical decision (PCI / CABG / OMT)
- If PCI, start with lesions producing the largest pressure step-up
- Repeat measurements after each treated segment and continue until FFR > 0.80
48 y.o. Male with angina CCS 2 and a positive bicycle stress test.
RCA
LAD
LAD pullback
Stent in prox LAD
FFR after prox stent
2:nd stent, distal stenosis
FFR after 2 stents
After 3:rd stent, mid LAD
Final functional result
MINI-FOCUS ON FRACTIONAL FLOW RESERVE
Clinical Research

Clinical and Physiological Outcomes of Fractional Flow Reserve-Guided Percutaneous Coronary Intervention in Patients With Serial Stenoses Within One Coronary Artery

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131 patients with multiple lesions within the same artery

- Composite FFR < 0.80
- Pressure pullback
- Primary culprit = largest pressure step-up
- Repeat pullback after PCI
- Repeat PCI until FFR > 0.80
Apparent vs true FFR in serial stenoses

\[ r = 0.601, p < 0.001 \]

(J Am Coll Cardiol Intv 2012;5:1013-8)
Clinical outcome (509 days)

- No events related to deferred lesions
- One target vessel revasc (in-stent restenosis)
- One nontarget vessel-related MI
- One noncardiac death
Summary

- Serial stenoses and diffuse disease represent a challenging diagnostic situation, often accompanied by therapeutic dilemmas.
- The contribution of individual lesions and diffusely diseased segments to "total FFR" is not easily appreciated at a first glance.
- Theoretical models accurately predict "true FFR" in serial lesions.
- In clinical practice, pull-back recordings with i.v. adenosine offer a useful diagnostic tool, permitting stepwise procedures with appropriate stenting of functionally significant lesions.