Pressure Wire Study

Fractional Flow Reserve (FFR)

Nishat Jahagirdar
Principal Clinical Cardiac Physiologist
Kings College Hospital
History


- The study is about the 50 patients who underwent POBA (then referred to as PTCA) over an 18 month period by Gruentzig.

- This paper illustrates how Gruentzig at that time believed in the value of coronary artery pressure measurements to assess coronary artery disease.

- FFR was termed in the Circulation in 1993 by Nico H J Pijls et al.

- RADI developed the first pressure wire in 1994.
NONOPERATIVE DILATATION OF CORONARY-ARTERY STENOSIS

Percutaneous Transluminal Coronary Angioplasty

Andreas R. Gröntzig, M.D., Åke Senning, M.D., and Walter E. Siegenthaler, M.D.
Ischemia

- Up to 60% stenosis of the coronary arteries can be compensated at rest and maximal exercise by vasodilation of the resistance coronary arteries.
  - These lesions do not have any benefits if treated with PCI + stents.

- Blockage of the coronary arteries in excess of 60% under conditions of increase in myocardial oxygen demand, will result in reduced perfusion and in turn ischemia.
  - These lesions should be treated with PCI + stents and there is a high probability that this will relieve the patient’s symptoms, improve quality of life and potentially reduce long-term risk of events.
Imaging Modalities

- Non invasive cardiac diagnostic tests (ETT, stress echo) help to determine if the patient has (stable or unstable) angina, but cannot help identify which lesion is the cause of the angina.

- Coronary angiogram is the ‘gold standard’ method to assess coronary artery anatomy.

- In case of a borderline lesion or to risk stratify the lesion other imaging modalities like IVUS and OCT can be used as an adjunct to angiography to assess lesion severity. But these findings cannot determine if that lesion is the cause of symptoms.

- Also, they can under and/or over estimate the lesion severity.
Why FFR?

- Fractional Flow Reserve (FFR) is a lesion specific, physiological index determining the hemodynamic severity of intracoronary lesions\(^1\).

- FFR can accurately identify lesions responsible for ischemia which in many cases would have been undetected or not correctly assessed by angiography or IVUS\(^2\) alone.

\(^2\) Tonino PM, et al. NEJM, 2009; 360:213-224
Perfusion Pressure

- Normal artery at maximum vasodilation:
  Perfusion pressure $\sim$ Aortic pressure (Pa).

- Stenotic artery:
  Perfusion pressure $\sim$ distal coronary pressure (Pd).

- Because at maximum vasodilation, blood flow is proportional to perfusion pressure, the ratio of maximum stenotic flow to normal maximum flow, can be expressed as a ratio of perfusion pressures.

- Therefore: FFR is linearly related to maximum flow.
Characteristics of FFR

- FFR is not influenced by changes in blood pressure, heart rate, or contractility.
- FFR has a unique normal value of 1.0 in every patient and every coronary artery.
- FFR incorporates the contribution of collateral flow to myocardial perfusion.
Pressure Wire

Distal Tip

Pressure Sensor
Calculation of FFR

- FFR is defined as the
  - Maximum achievable blood flow in stenotic coronary artery (Pd) divided by Maximum blood flow in the same artery without stenosis (Pa).

- Hence at Maximum Hyperemia; \( \text{FFR} = \frac{\text{Pd}}{\text{Pa}} \)

\[ \text{Pa} \text{ (AO pressure via catheter)} \]
\[ \text{Pd} \text{ (PressureWire)} \]
Adenosine

- Half life < 10 seconds.

- Can be given as:
  - IV infusion which can be administered at a rate of 140 micrograms/kilogram/minute for two minutes.
  - Intra coronary bolus doses.

- Patients will often complain of chest tightness and dyspnoea and there will be a transient rise in blood pressure before the Pd value reduces and adopts an ischaemic waveform with diastolic blunting.

- PR prolongation or transient heart block can occur which can also be used as surrogate measures of maximal hyperaemia.
Adenosine (contd)

- Caffeine's purine structure binds to some of the same receptors as Adenosine and the pharmacological effects of adenosine may therefore be blunted.

- Contraindications
  - Asthma
  - Second- or third-degree heart block
  - Sick sinus syndrome (without a pacemaker)
  - Long QT syndrome
  - Severe hypotension
  - Decompensated heart failure
  - Poison/ drug-induced tachycardia
Normal FFR

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

As mentioned earlier, at maximal hyperemia \( P_a = P_d \), hence

Normal coronary artery \( FFR = 1.0 \)
FFR = $\frac{P_d}{P_a}$

At maximal hyperemia, due to stenosis $P_d < P_a$

For example;
$P_a = 100\text{mmHg}$
$P_d = 70\text{mmHg}$

Then $\text{FFR (stenosis)} = \frac{70}{100} = 0.7$
Pitfalls

- **Guide wire introducer / Y connector**
  - During equalizing of pressures, measuring FFR and checking for drift at the end of the procedure, the wire introducer needs to be removed as there is a subtle leak (<10mmHg) of aortic guiding catheter pressure via this device.

- **Clear the catheter of contrast**
  - To avoid subtle contrast induced damping of pressure waveform, during equalizing of pressures and FFR measurement.

- **Guiding Catheter with side holes**
  - Always disengage the guiding catheter because the side holes may actually change the true proximal coronary pressure measurement.
Pitfalls (contd)

- Damping of pressure by the guiding catheter:
  - Especially with ostial lesions and when using large guiding catheters.
  - The guiding catheter needs to be pulled back to prevent damping, otherwise the obtained FFR value will be artificially higher and the true severity of the stenosis underestimated.

- Signal Drift
  - High fidelity equipment make problems of signal drift less likely, however the problem can still occur.
  - This issue is detected when an apparent gradient appears between Pd and Pa without a change in waveform of the distal pressure.
  - It should be checked for at the end of the FFR procedure by ensuring that equalization still holds true when the coronary wire is withdrawn back into the guiding catheter.
Maximal Hyperaemia

- There is no such thing as a resting FFR.
- It is only at maximal hyperaemia that resistance is minimal and that flow develops a linear relationship to pressure - a vital prerequisite for the FFR equation to hold true.
- Not achieving maximal hyperaemia will usually overestimate the FFR value and therefore underestimate the true severity of a coronary stenosis.
PCI / Revascularisation

0

Gray Zone

0.75

Rx

0.8

1.0

? Intervention

Ischemia Present

No Ischemia
Positive FFR + Pullback

FFR is positive and pullback of the wire shows a step-up in FFR, proximal to the lesion.
There is a drop in pressures after Adenosine infusion, but FFR remains at a steady state.
CHB induced due to Adenosine.
Breathing

Blood pressure variance with respiration.
ESC Guidelines on Myocardial Revascularisation

Only FFR and DES are Class IA indications for PCI.
Questions?