Do we need both pressure and flow?

Nils P. Johnson, MD, MS, FACC
Assistant Professor of Medicine
Division of Cardiology, Department of Medicine
and the Weatherhead P.E.T. Imaging Center
University of Texas Medical School at Houston
Memorial Hermann Hospital – Texas Medical Center
Houston, Texas, United States of America
Disclosure Statement of Financial Interest

Within the past 12 months, Nils Johnson has had a financial interest/arrangement or affiliation with the organization(s) listed below.

**Affiliation/Financial Relationship**
- Grant/Research Support (*pending* to institution)
- Non-disclosure agreements (non-financial)

**Company**
- St Jude Medical
- Volcano Corporation
- St Jude Medical
- Volcano Corporation

However, Nils Johnson has *never* personally received *any* money from *any* commercial company.
71 year-old man who presented with abnormal SPECT:

- Modifiable risk factor:
  - Hypertension (treated with beta blocker)

- Symptoms
  - None with typical daily activities
  - Occasional palpitations and non-exertional chest discomfort, but mild and brief
  - Classic but mild angina once when digging a ditch in very hot weather

- Workup
  - Unremarkable echocardiogram and Holter
  - Treadmill showed no angina but 2mm ST depression after 6:30 minutes of Bruce protocol
  - SPECT showed partially reversible inferolateral defect
“topographic” PET map (3D into 2D)

Johnson NP, *JACC Cardiovasc Imaging*. 4(9):990, 2011, Figure 1

Wikipedia “Goode homolosine projection”
http://www.sos.noaa.gov/Education/earth_system.html
“atlas”
high resolution

“color scheme”
relative uptake

normal
mild
>75% max

mild
moderate
50-75% max

moderate
severe
<50% max

Nakagawa Y, J Nucl Cardiol. 8(5):580, 2001, Figure 1
**Case.** 71 year-old man with one episode of mild angina

Dipyridamole produced *no angina* and *no significant ST depression*. 
**bolus** + **tracking** = **flow**

**cath lab**
- Cold saline

**PET lab**
- "Hot" radiotracer

**time-temperature curve**
- L/min (cardiac output)

**time-activity curve**
- cc/min/gm (myocardial perfusion)
PET “physiology-gram”:

- CFR < 1 in OM1/OM2 distribution implies total occlusion supplied by collaterals
- CFR = 2.6 in LAD distribution

worst CFR = 0.95 (myocardial steal)
Total occlusion of large OM branch supplied by collaterals
Small caliber, codominant RCA with mid lesion
Calcified trifurcation lesion in mid LAD
PET: LAD
CFR = 2.6
Pressure (mmHg) vs. Time (seconds)

- aortic
- coronary

rest Pd/Pa = 0.88
FFR = 0.58
PET: LAD
CFR = 2.6

**discordance**

CFR > 2.0   FFR ≤ 0.8

rest Pd/Pa = 0.88

mid LAD
FFR = 0.58
Invasive tools to estimate flow

- Doppler velocity
- Bolus thermodilution
- Continuous thermodilution
- Thermal anemometry

Pijls NH, Circulation. 105(21):2482, 2002, Figure 2
Aarnoudse W, JACC. 50(24):2294, 2007, Figure 7
Based on Johnson NP, *JACC Cardiovasc Imaging*. 5(2):193, 2012, Figure 1 (plus 120 new lesions)
Based on Johnson NP, JACC Cardiovasc Imaging. 5(2):193, 2012, Figure 1 (plus 120 new lesions)
Model parameters:

- **LMCA diameter:** 4.4 mm
- **LMCA length:** 1 cm
- **LAD total length:** 18 cm
- **LCx total length:** 11 cm
- **Aortic pressure:** 100 mmHg
- **Venous backpressure:** 10 mmHg
- **Diffuse disease:** variable
- **Focal stenosis:** variable
Johnson NP, *JACC Cardiovasc Imaging*. 5(2):193, 2012, Supplement Figure F2

- Increasing *focal* disease
- Increasing *diffuse* disease
- Diameter stenosis = 0%
- None
- Mild
- Moderate
- Severe
Figure 3. Conceptual Plot of CFR and Fractional Flow Reserve Regions

Johnson NP, *JACC Cardiovasc Imaging*. 5(2):193, 2012, Figure 3
Universal CFR/FFR triangle

CFR by PET
Texas (2012)
43% discordance

CFR by thoracic echo
Japan (2014)
35% discordance

CFR by thermo
Madrid (2013)
44% discordance

PET = Johnson NP, JACC Cardiovasc Imaging. 5(2):193, 2012, Figure 1B
Thoracic echo = Wada T, Eur Heart J Cardiovasc Imaging. 15(4):399, 2014, Figure 6
Thermodilution = Echavarria-Pinto M, Circulation. 128(24):2557, 2013, Figure 1B
“... regional contractile function is dependent on subendocardial blood flow and is independent of coronary perfusion pressure”

Figure 3. Percent segmental shortening during the ejection period in 10 chronically instrumented dogs during the control state and with circumflex artery depressurization. Mean values ± 1 standard deviation appear on either side of individual data.

<table>
<thead>
<tr>
<th>Control Pressure</th>
<th>Low Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant Flow</strong></td>
<td><strong>Constant Flow</strong></td>
</tr>
<tr>
<td>Pd/Pa = 83/92</td>
<td>Pd/Pa = 38/88</td>
</tr>
<tr>
<td>= 0.90</td>
<td>= 0.43</td>
</tr>
</tbody>
</table>

*Ten Dogs
One experiment each
p = NS
no PCI!
since
FFR > 0.8
(DEFER, FAME, FAME 2)
yes PCI! since FFR ≤ 0.8 and CFR < 2
need PCI?
despite $\text{FFR} \leq 0.8$
since $\text{CFR} \geq 2$
despite *same* FFR
different CFR
thus, different treatments?

need PCI?

**yes PCI!**
since FFR ≤ 0.8
and CFR < 2

since CFR ≥ 2
Referred for CABG:
- LIMA-LAD
- SVG-DIAG
- SVG-OM
- SVG-RCA
PET flow in LAD during hyperemia:
- Before CABG = 1.78 cc/min/gm
- After CABG = 2.82 cc/min/gm
- Flow ratio before/after = 1.78/2.82 = 0.63
- Invasive, pressure-derived FFR = 0.58
“... pressure and flow represent the two sides of the same coin ... from the physiologic point of view, both techniques are highly complementary.”