Tandem lesions, diffuse disease

FFR and resting physiology

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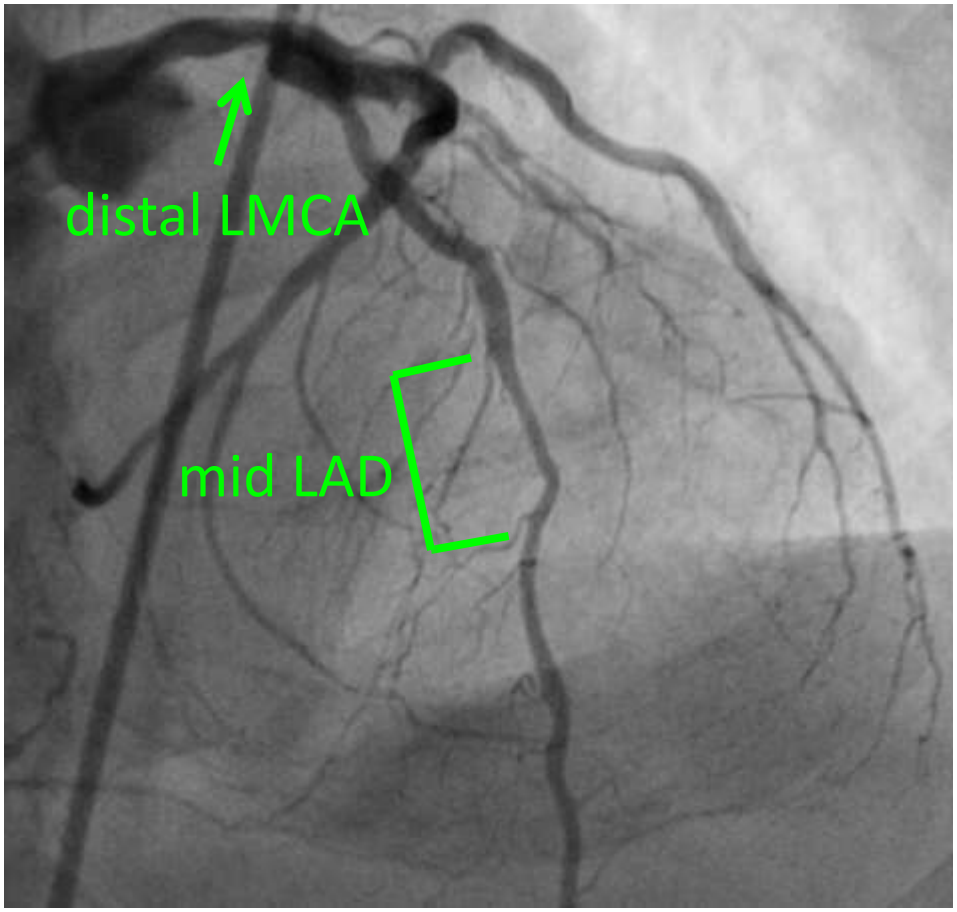
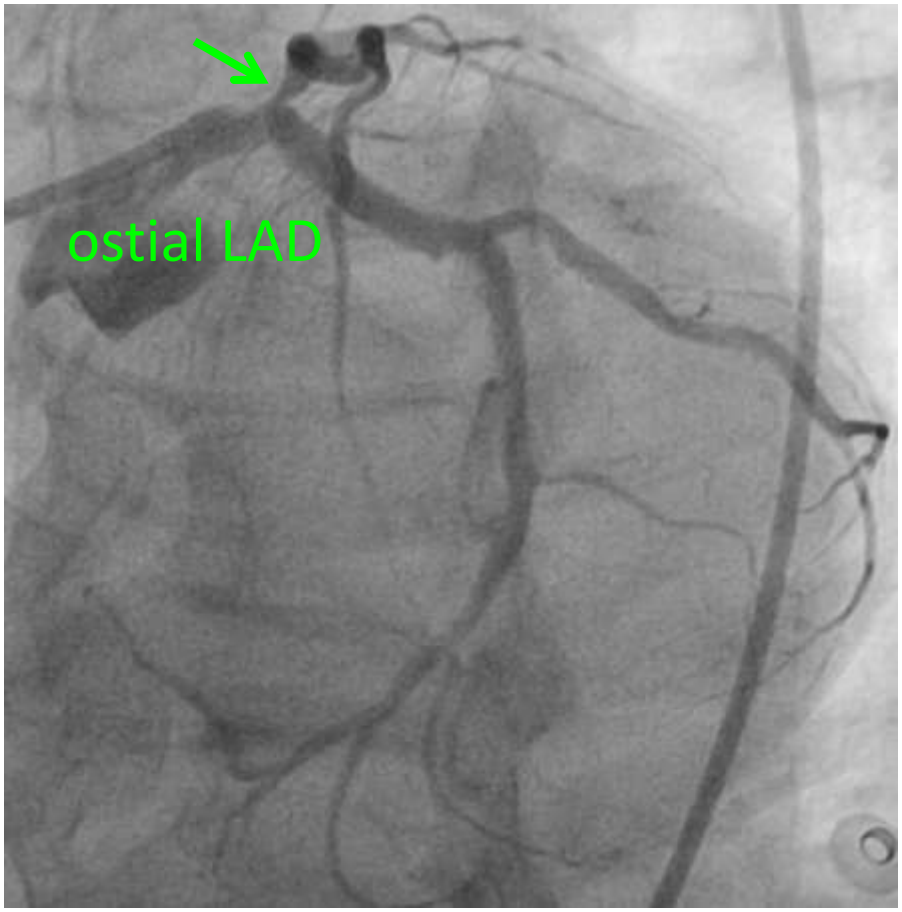
Disclosure Statement of Financial Interest

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

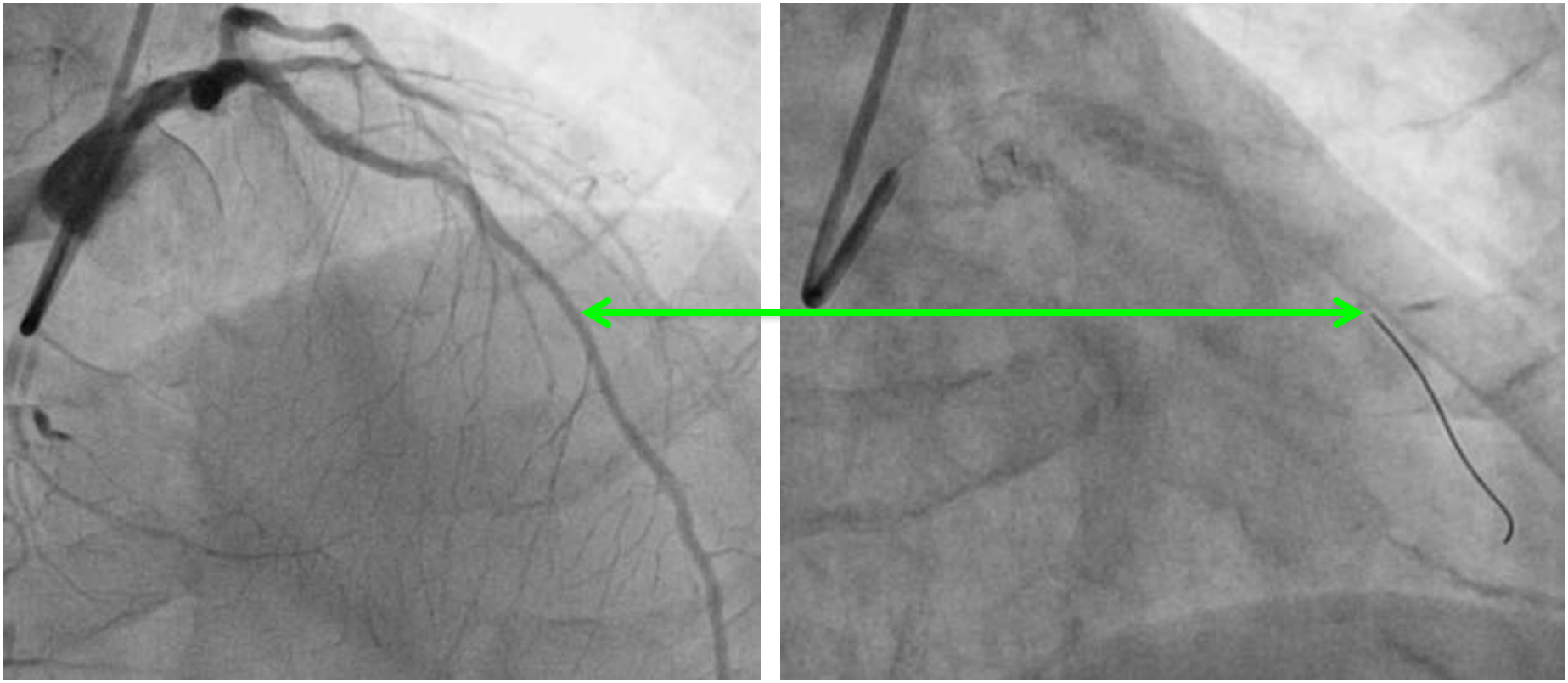
Affiliation/Financial Relationship	Organizations (alphabetical)
• Grant/research support (to *institution*)	• St Jude Medical (for CONTRAST study) • Volcano/Philips (for DEFINE-FLOW study)
• Licensing and associated consulting (to *institution*)	• Boston Scientific (for smart-minimum FFR algorithm)
• Support for educational meetings/training (honoraria/fees donated to *institution*)	• Various, including academic and industry

Serial LMCA and LAD lesions

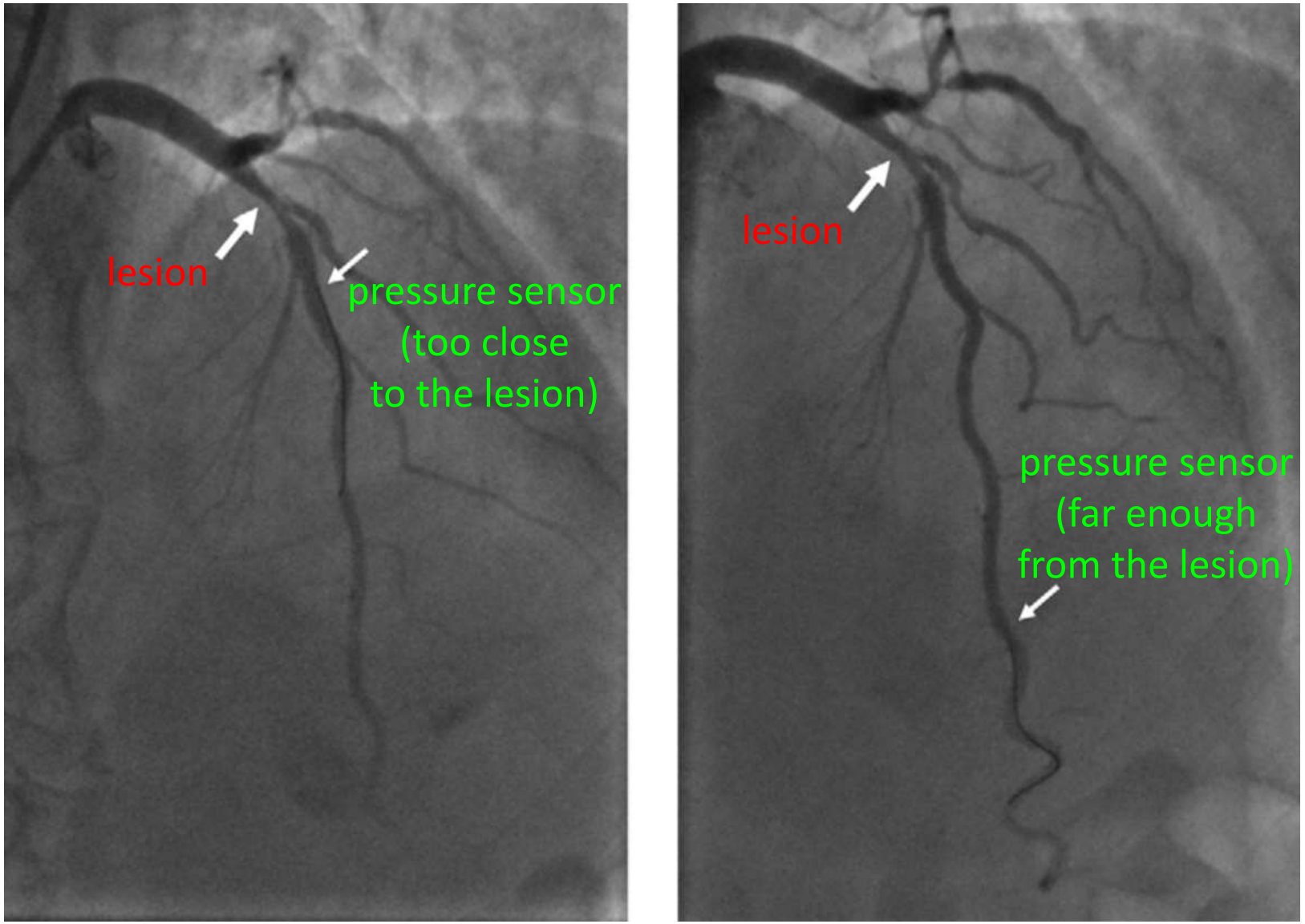




Place pressure wire *distal* to all lesions

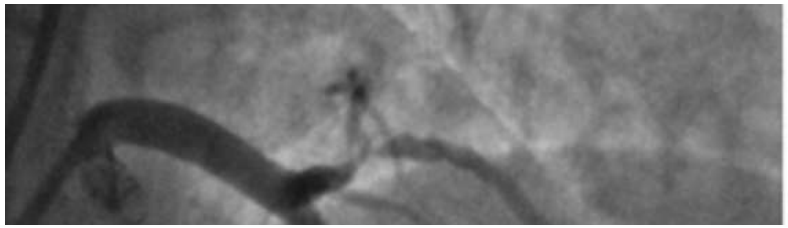


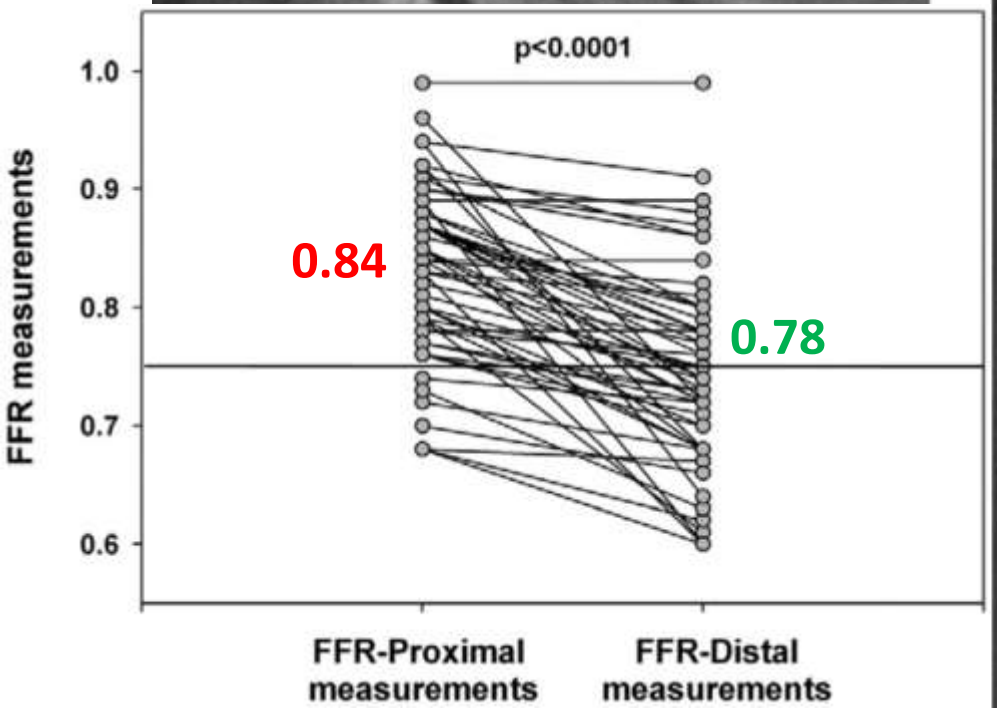
How distal is far enough?

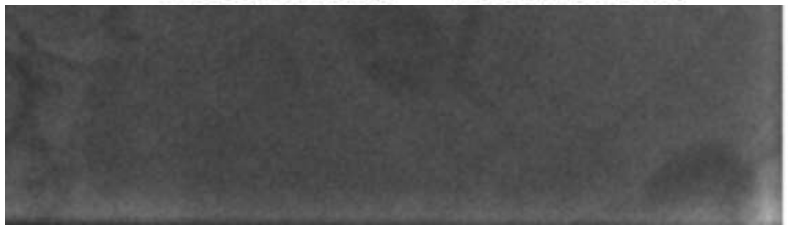


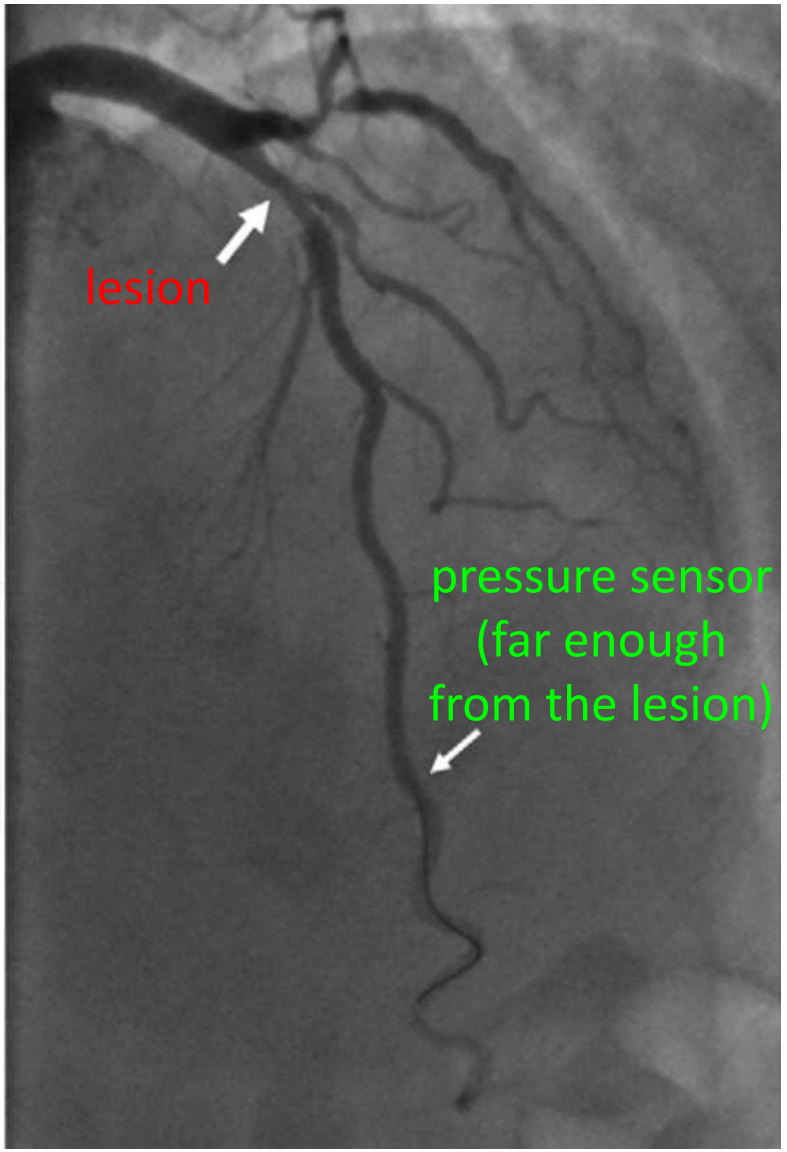
Rodés-Cabau J, *Am J Cardiol*. 2011 Aug 15;108(4):483-90. (Figure 1 with my annotations)

Most distal = all focal + diffuse



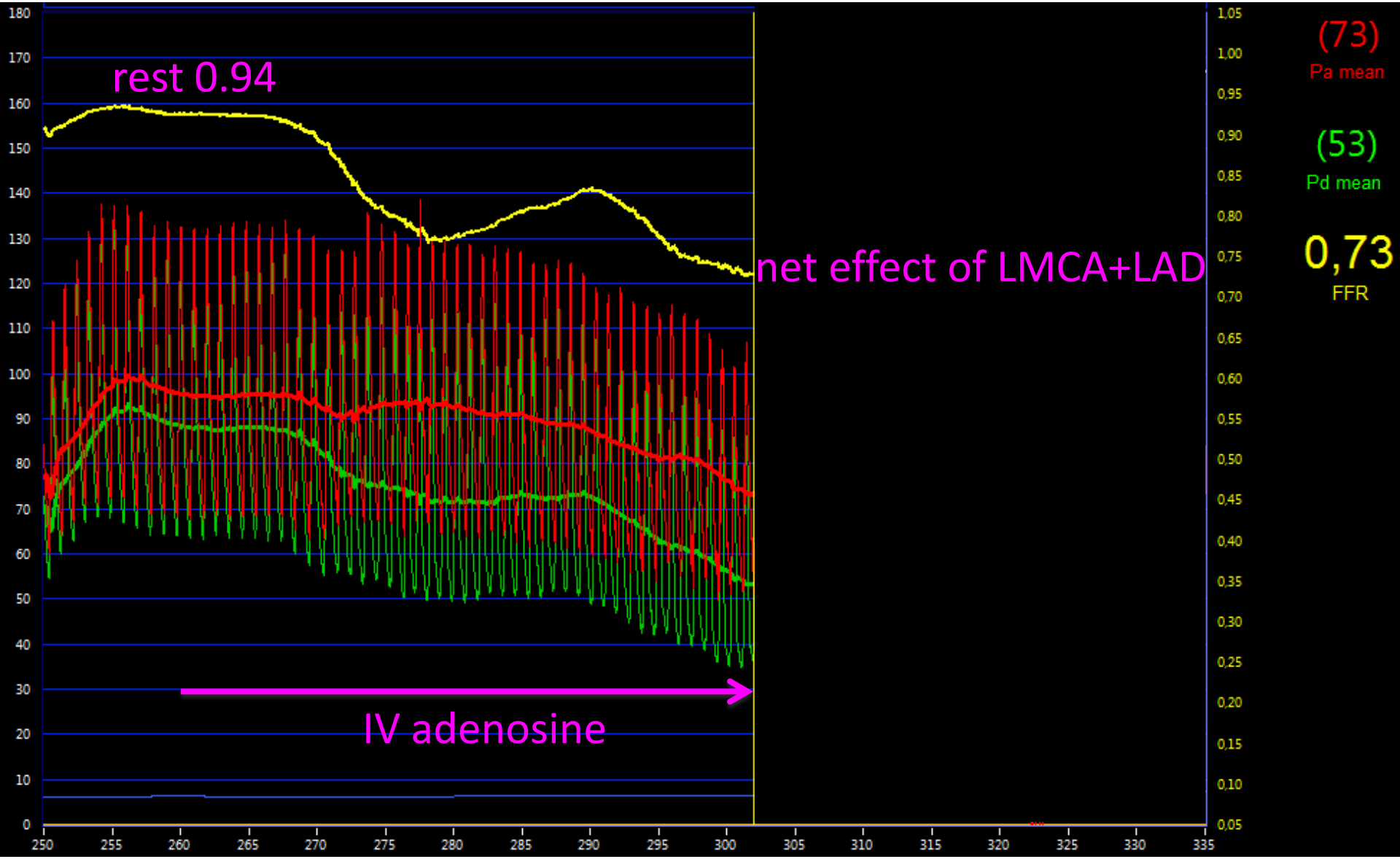




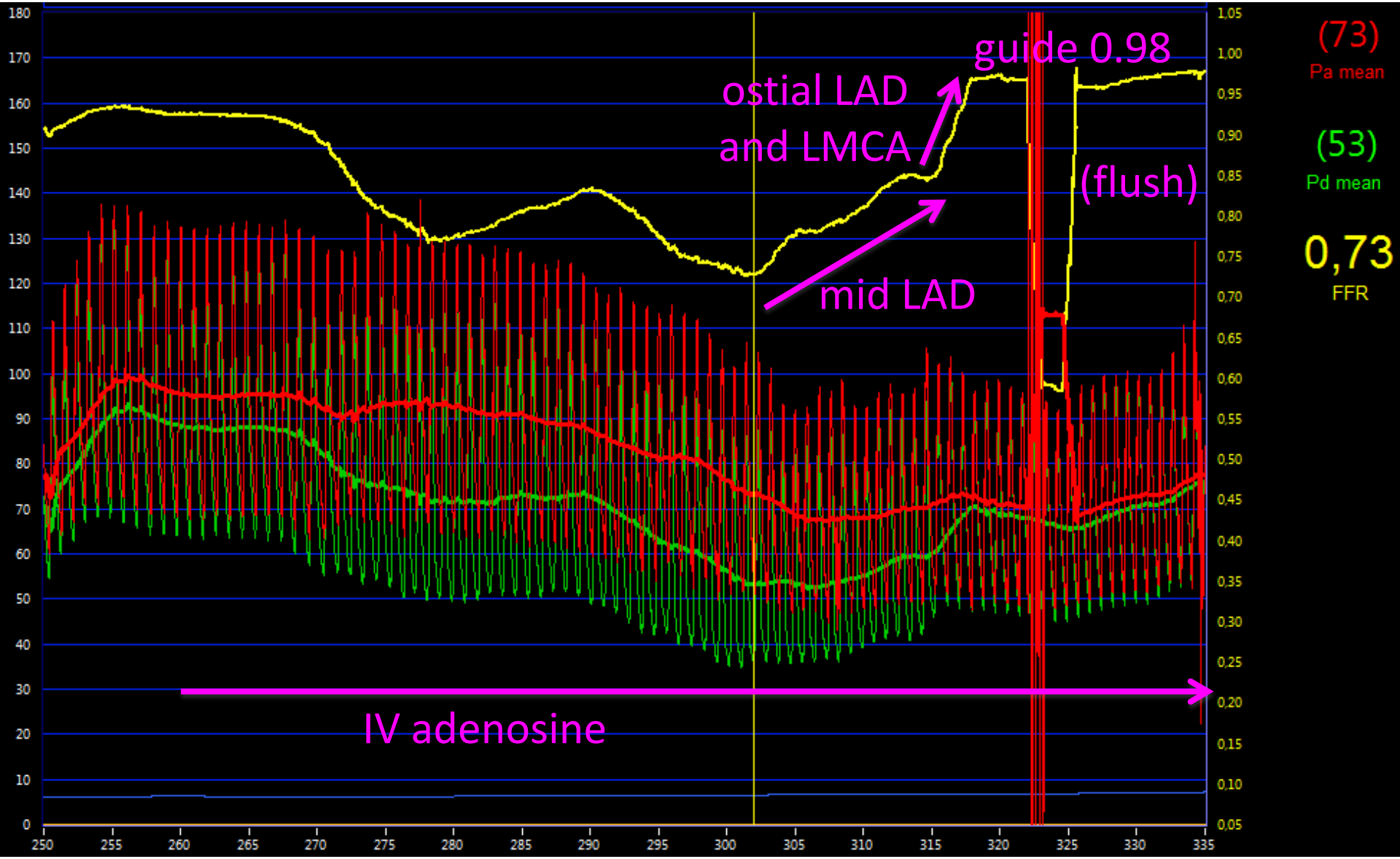


Rodés-Cabau J, *Am J Cardiol*. 2011 Aug 15;108(4):483-90. (Figure 1+3 with my annotations)

Start IV adenosine to assess *net* effect

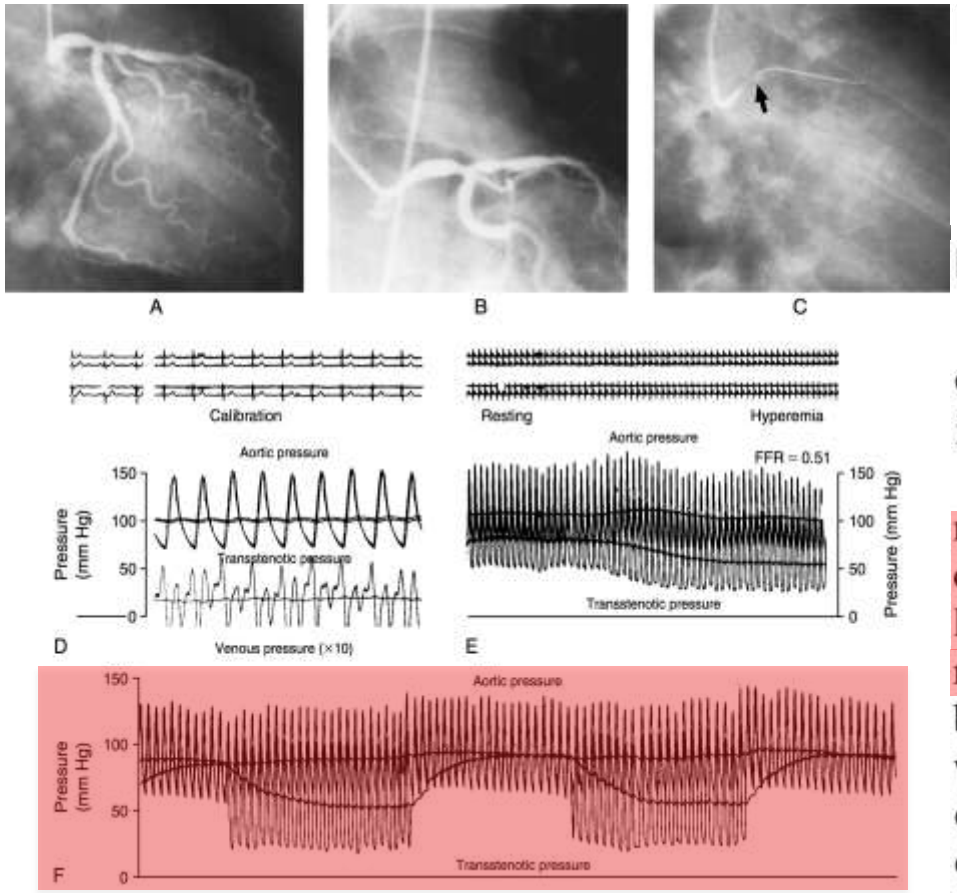


Move pressure sensor back to guide



Pullback curve: fundamental technique

1996 NEJM



2000 review

Practice and Potential Pitfalls of Coronary Pressure Measurement

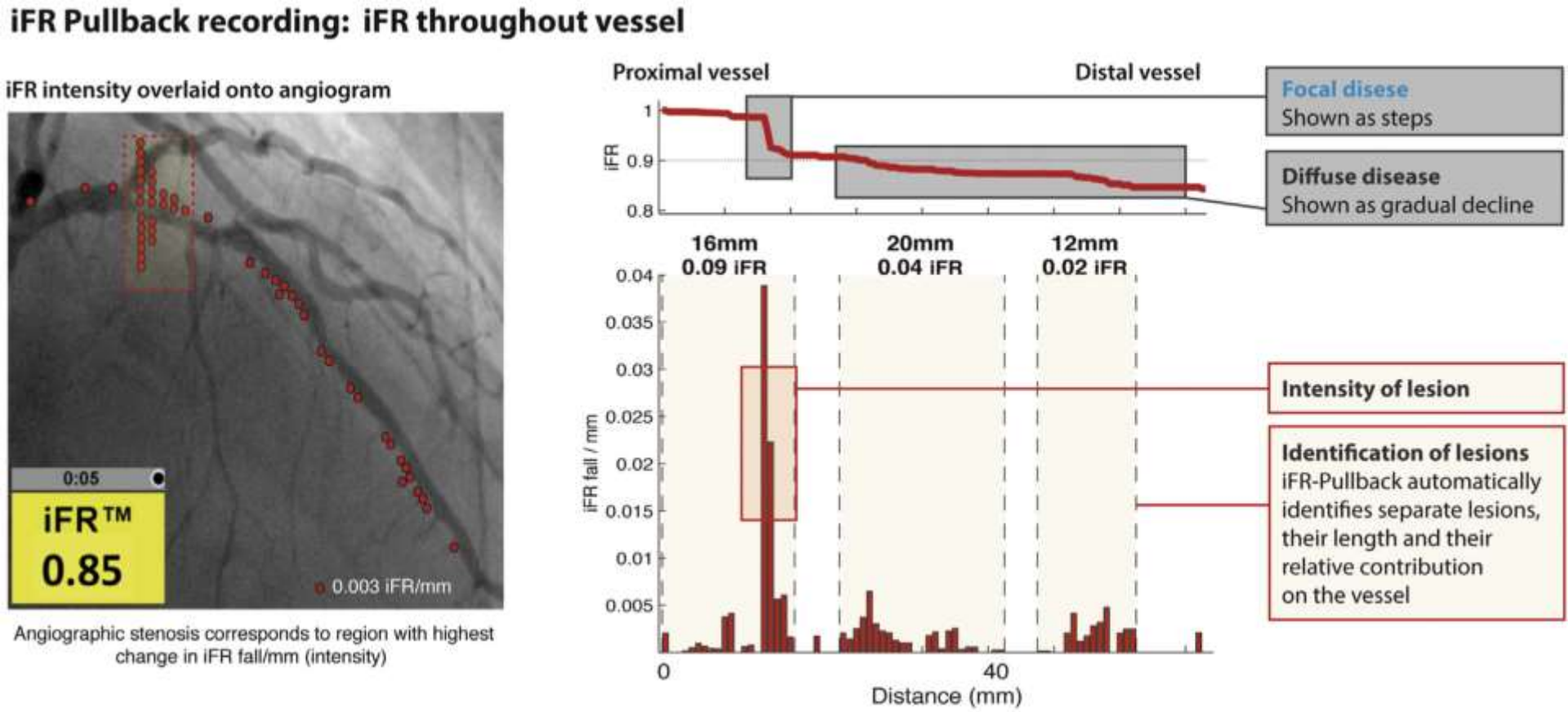
Nico H.J. Pijls,[1]* MD, PhD, Morton J. Kern,[2]† MD, Paul G. Yock,[3]† MD and Bernard De Bruyne[4] MD, PhD

Pullback Pressure Recordings

The most convincing and reproducible demonstration of the exact location and severity of a coronary stenosis is the so-called pressure pullback curve (Fig. 5). If a large resting gradient is already present and the main purpose of the pullback recording is to determine the exact location of the stenosis, additional hyperemia is not required during the pressure pullback curve. The pullback curve also enables the assessment of serial lesions within one vessel (Fig. 6) or the presence of diffuse disease (gradually decreasing hyperemic pressure gradient during pullback from distal coronary artery to coronary ostium; Fig. 7)

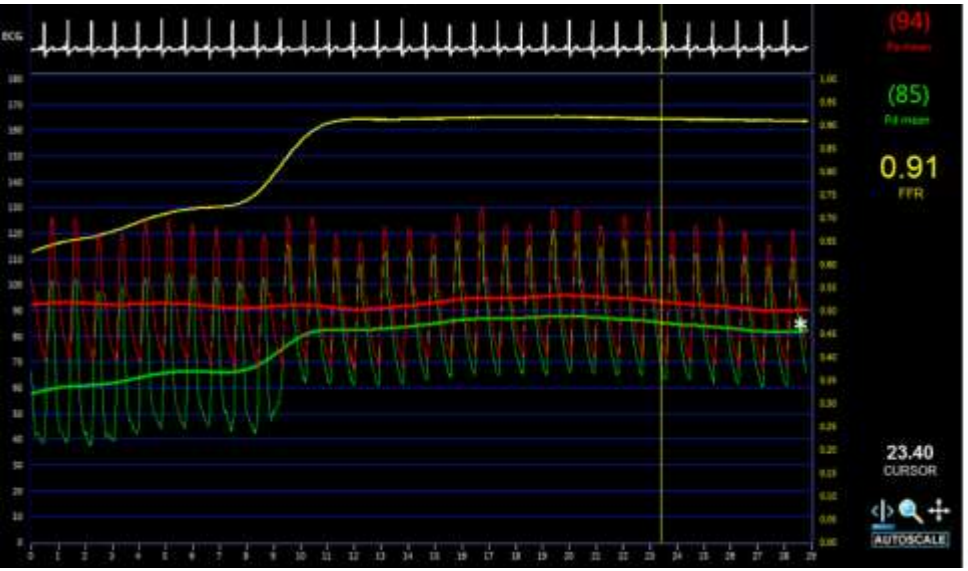
left = Pijls NH, *NEJM*. 1996 Jun 27;334(26):1703-8. (Figure 1)
right = Pijls NH, *Catheter Cardiovasc Interv*. 2000 Jan;49(1):1-16. (Text excerpts)

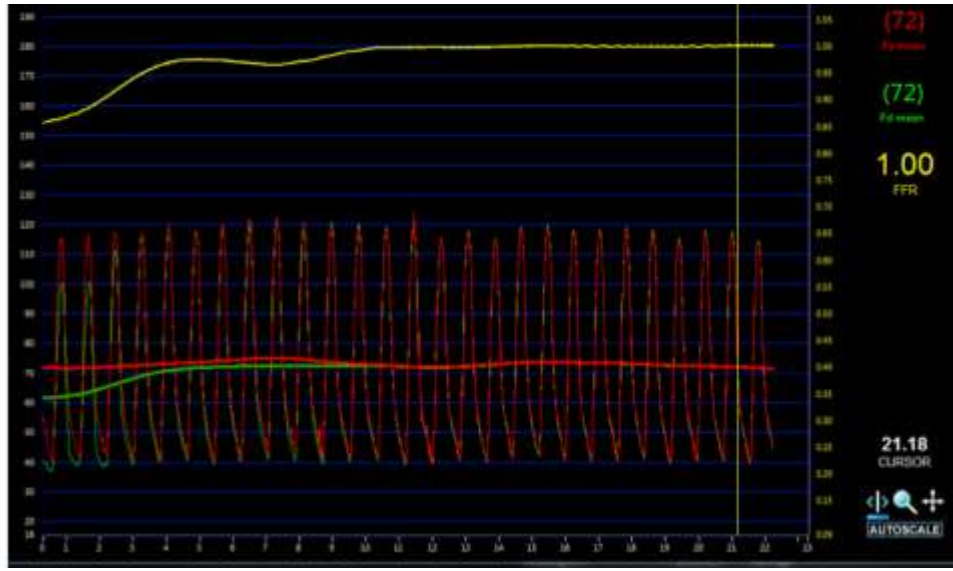
Overlay of pullback and angiogram



Nijjer SS, *JACC Cardiovasc Interv*. 2014 Dec;7(12):1386-96. (Figure 3A)

Pullback information #1: *drift*



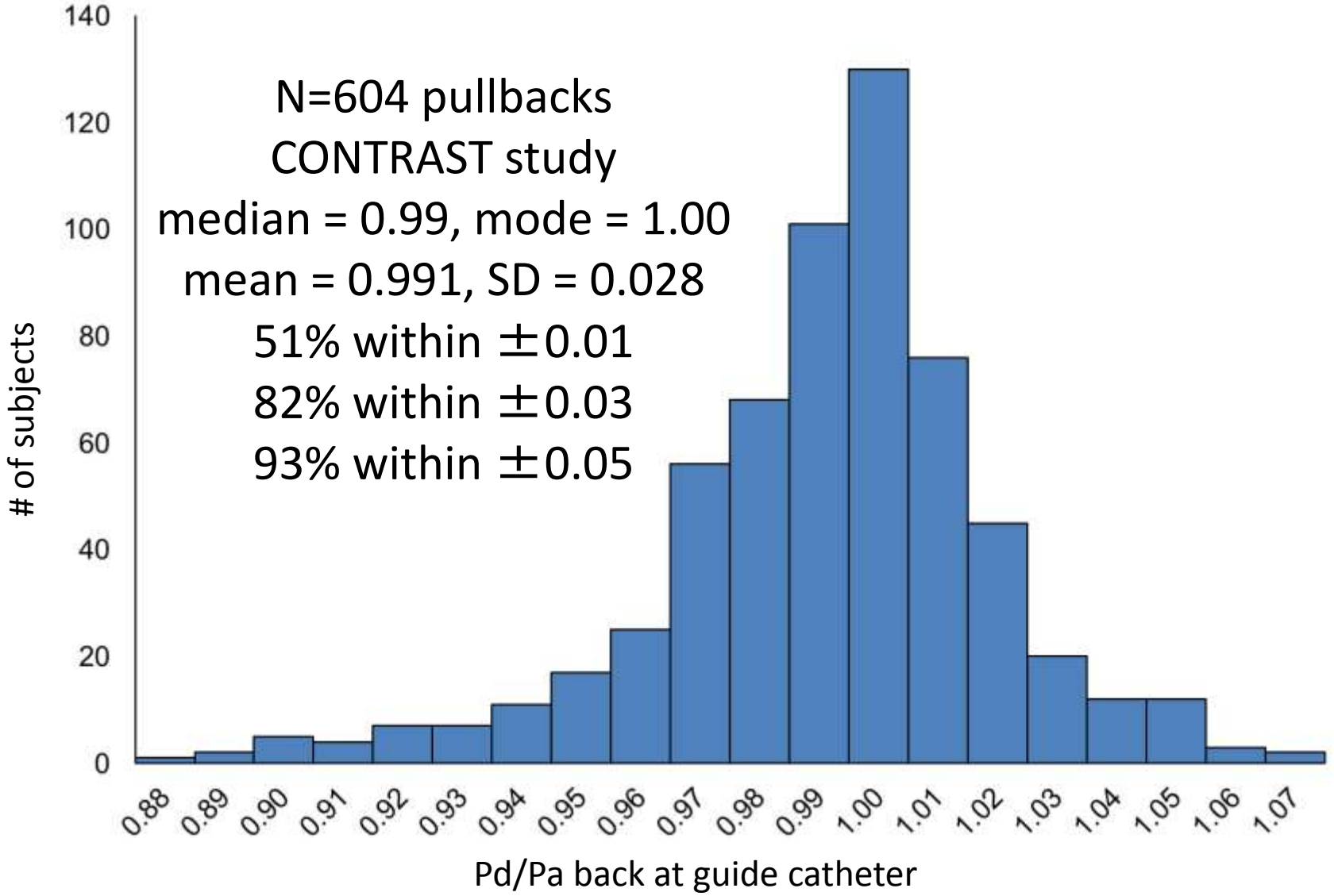


Pd/Pa=0.91
back at guide
→ *drift*!

Pd/Pa=1.00
back at guide
→ *no drift*!

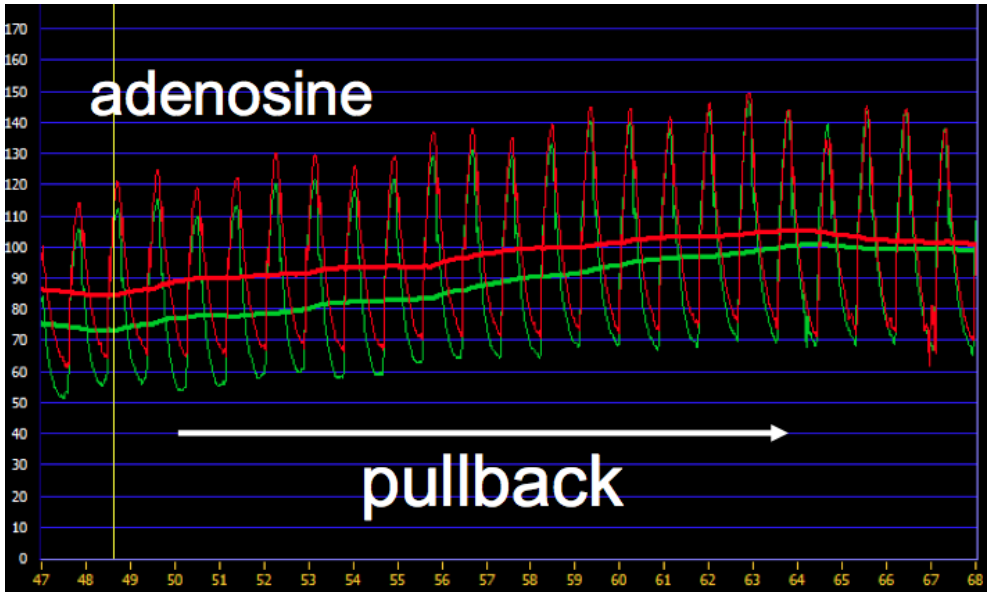
Jeremias A, manuscript under review

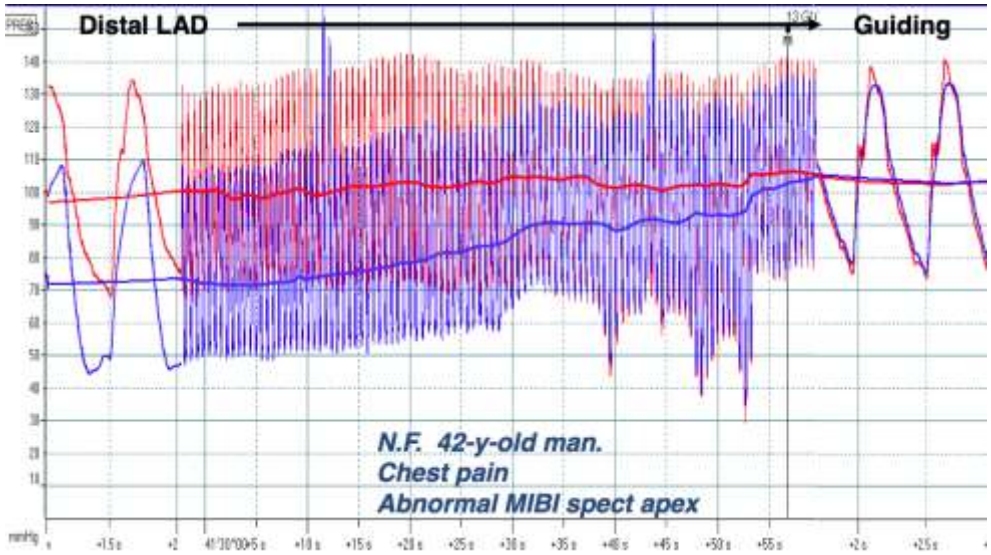
How much *drift* can we expect?



Jeremias A, manuscript under review (analysis from CONTRAST supplement added to figure)

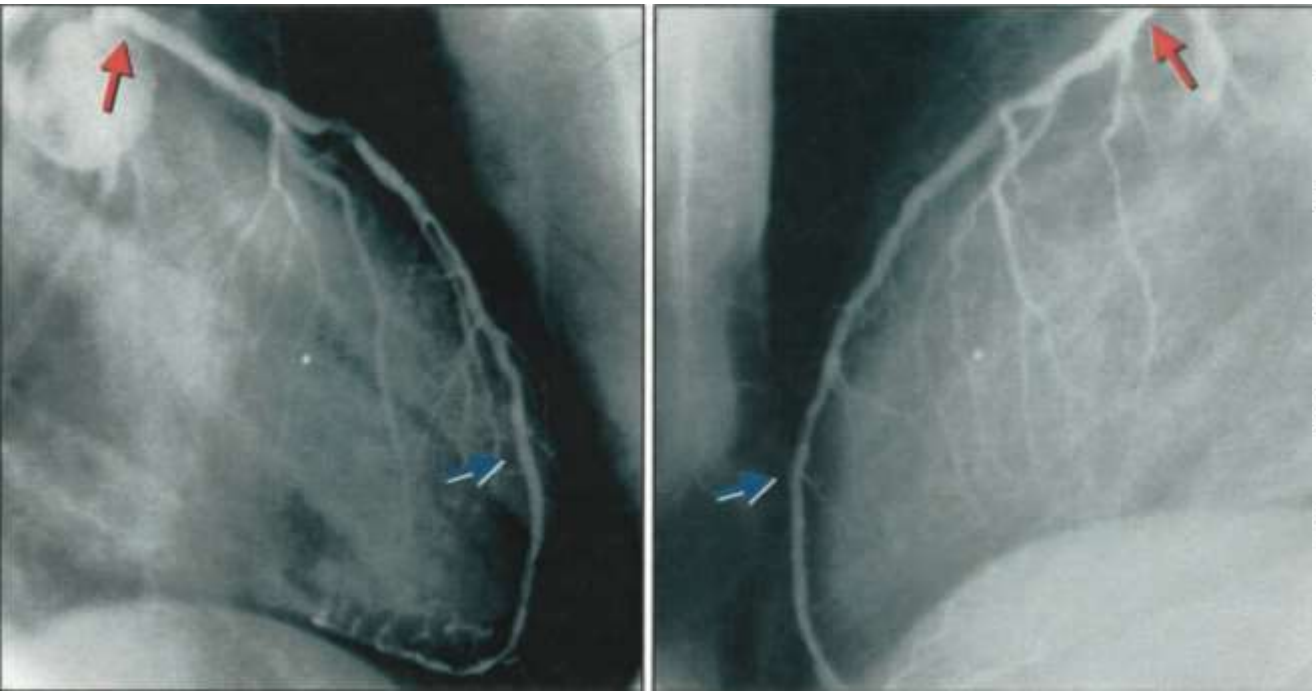
Pullback information #2: *diffuse*

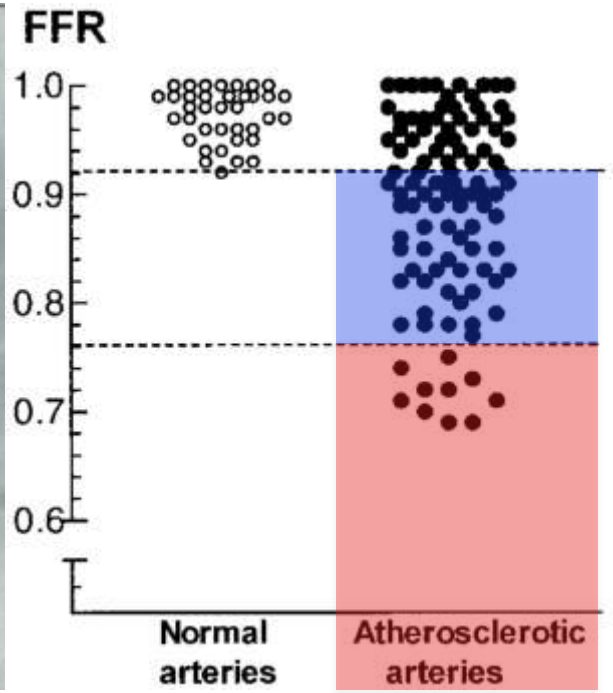




Various pressure tracings from ETP and TCT presentations (De Bruyne, Pijls)

Diffuse disease common in CAD





44 year-old man, stable angina

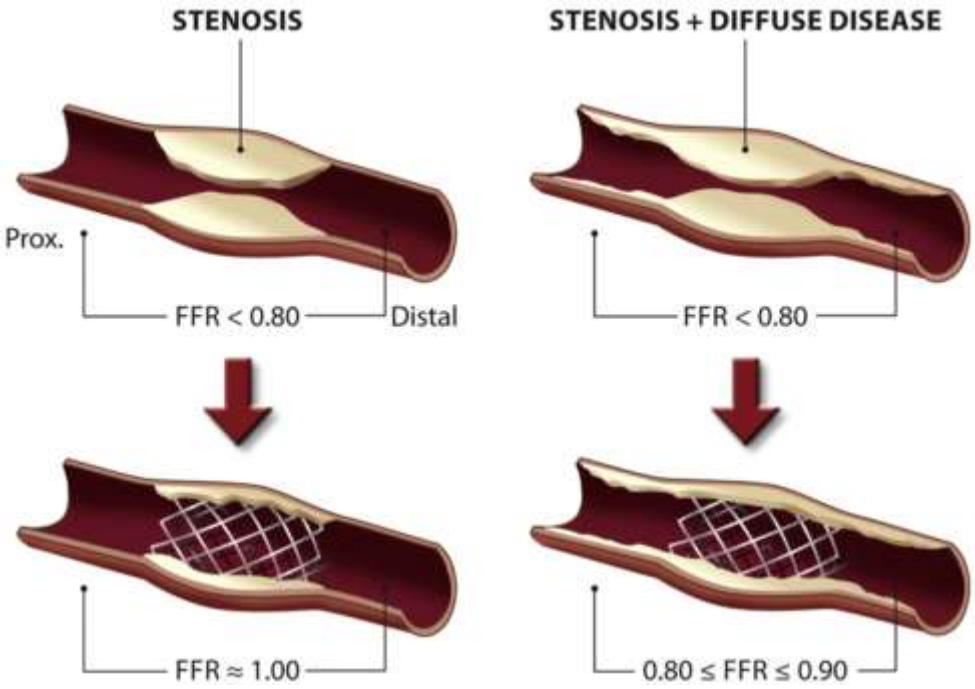
FFR 0.76 distally, Pa-Pd=23mmHg

but diffuse on pullback

- N=106 with CAD
- All diffuse on pullback
- 8% with FFR<0.75
- 57% with FFR<0.92

De Bruyne, *Circulation*. 2001 Nov 13;104(20):2401-6. (Figure 2 top and Figure 3 annotated plus results from text)

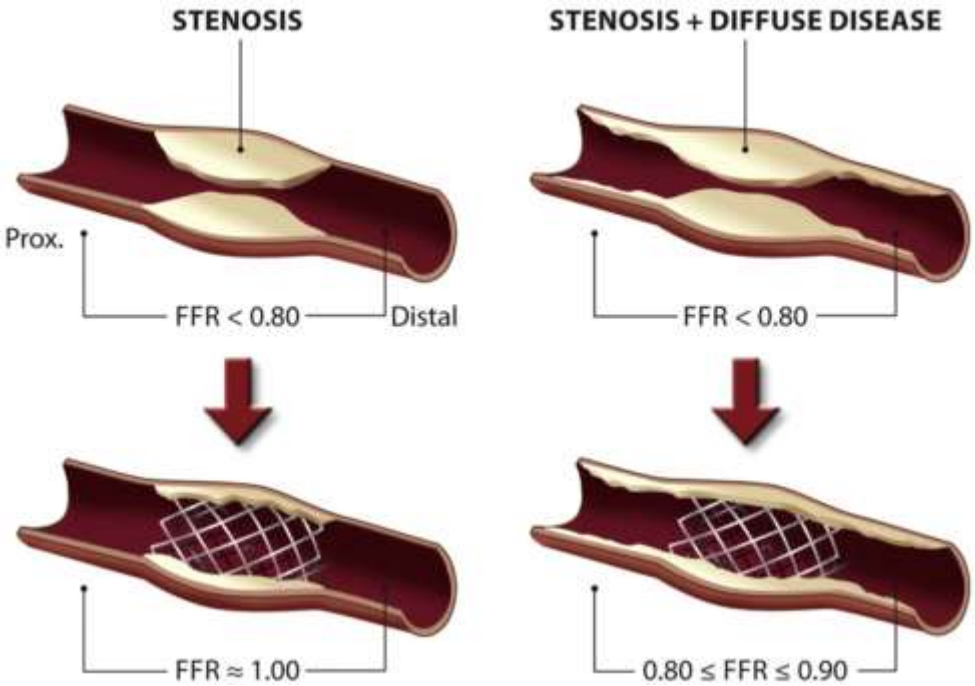
Post-PCI FFR ≈ diffuse disease burden

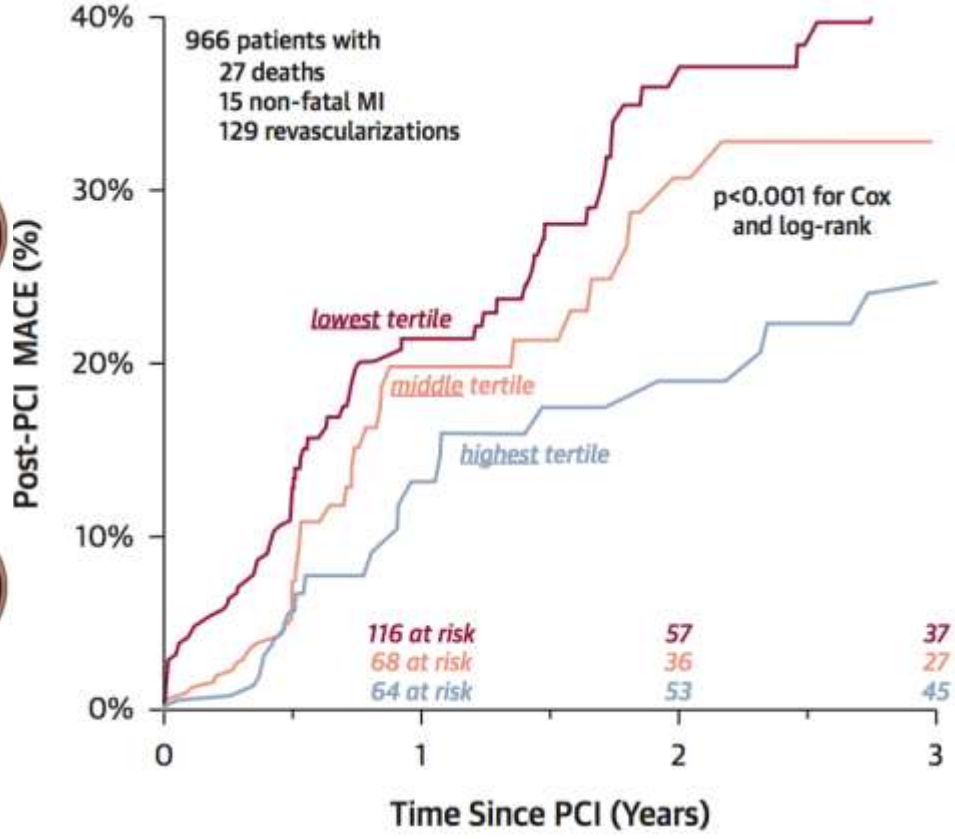


FFR measured *AFTER* stenting
Focal disease largely gone
Diffuse disease left behind

left = Rimac G, *Am Heart J*. 2017 Jan;183:1-9. (Figure 7)

Diffuse disease impacts prognosis

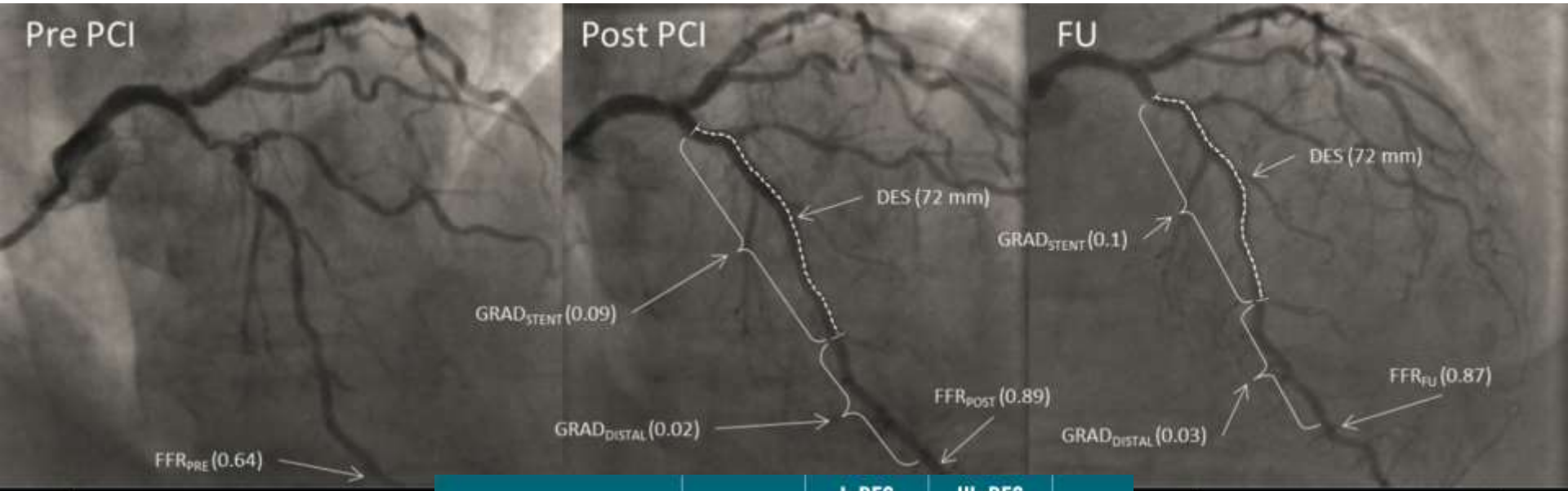


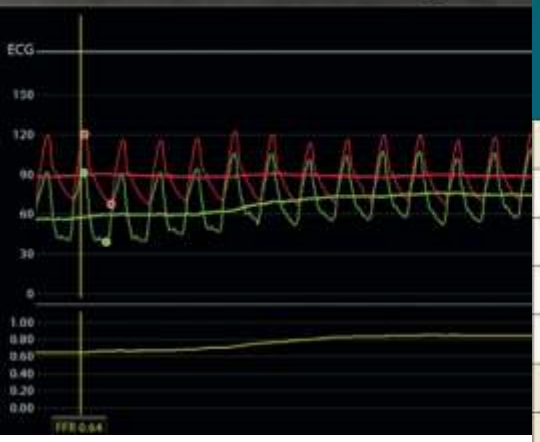


FFR measured *AFTER* stenting
Focal disease largely gone
Diffuse disease left behind

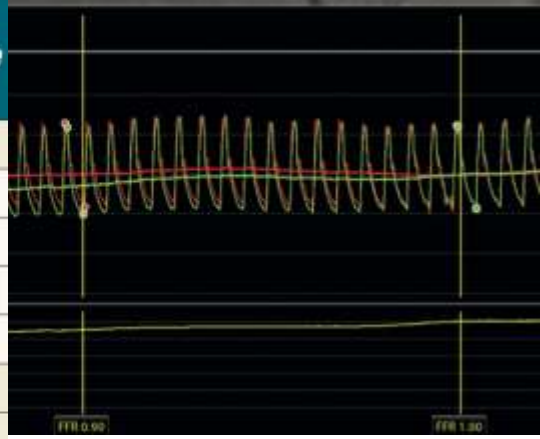
left = Rimac G, *Am Heart J*. 2017 Jan;183:1-9. (Figure 7)
right = Johnson NP, *JACC*. 2014 Oct 21;64(16):1641-54. (Figure 4A)

Treat diffuse disease with PCI?



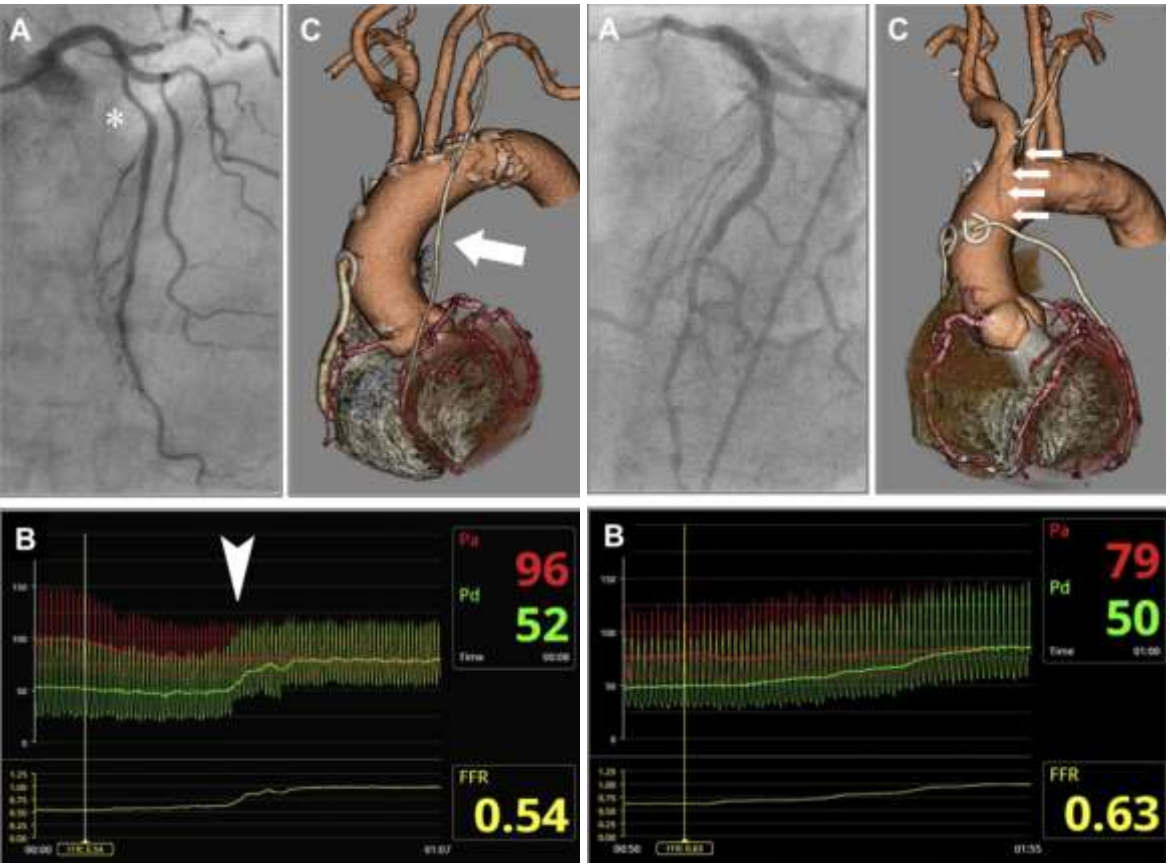


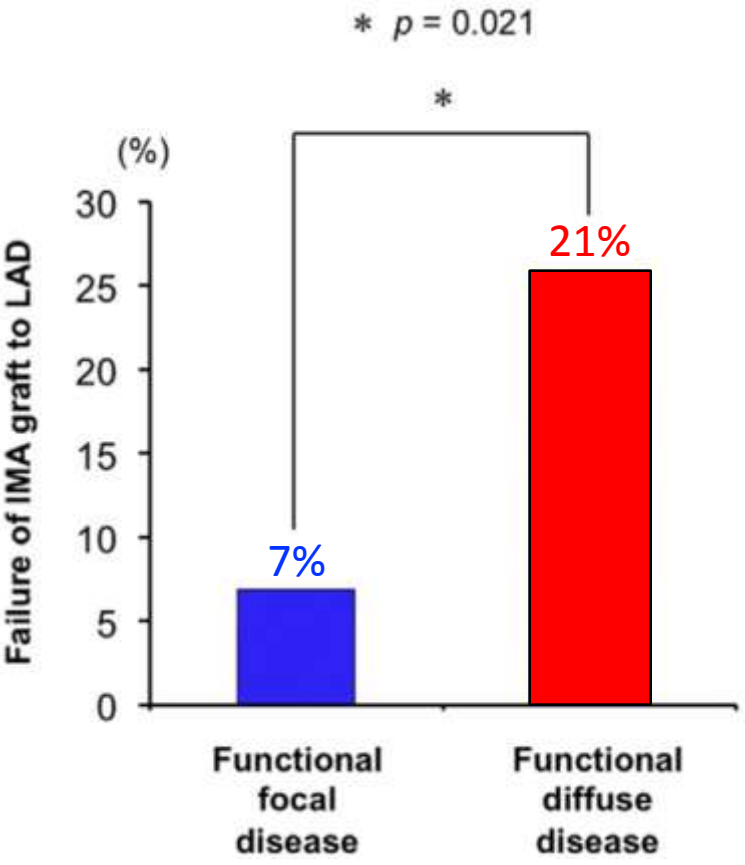
	All patients n=74	L-DES (≤50 mm) n=37	UL-DES (>50 mm) n=37	*p-value*
Baseline (FFR$_{PRE}$)	0.61±0.11	0.64±0.11	0.57±0.11	0.007
Post PCI	n=74	n=37	n=37	
FFR$_{POST}$	0.88±0.06	0.89±0.07	0.87±0.04	0.05
GRAD$_{STENT}$	0.06±0.03	0.04±0.03	0.07±0.03	0.001
GRAD$_{DISTAL}$	0.05±0.05	0.04±0.05	0.06±0.05	0.25
Follow-up	n=61	n=31	n=30	
FFR$_{FU}$	0.85±0.08	0.86±0.08	0.85±0.09	0.48
GRAD$_{StentFU}$	0.07±0.07	0.05±0.05	0.09±0.08	0.04
GRAD$_{DistalFU}$	0.05±0.04	0.05±0.05	0.04±0.03	0.38



Baranauskas A, *EuroIntervention*. 2016 Dec 20;12(12):1473-1480. (Figure 1 and Table 3)

Treat diffuse disease with LIMA?





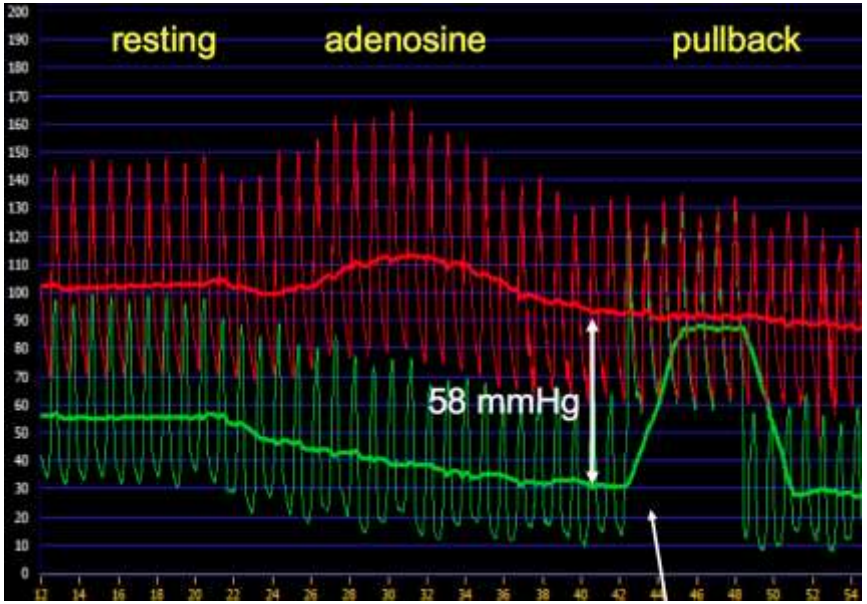
Focal disease
Patent LIMA
@ 3 months

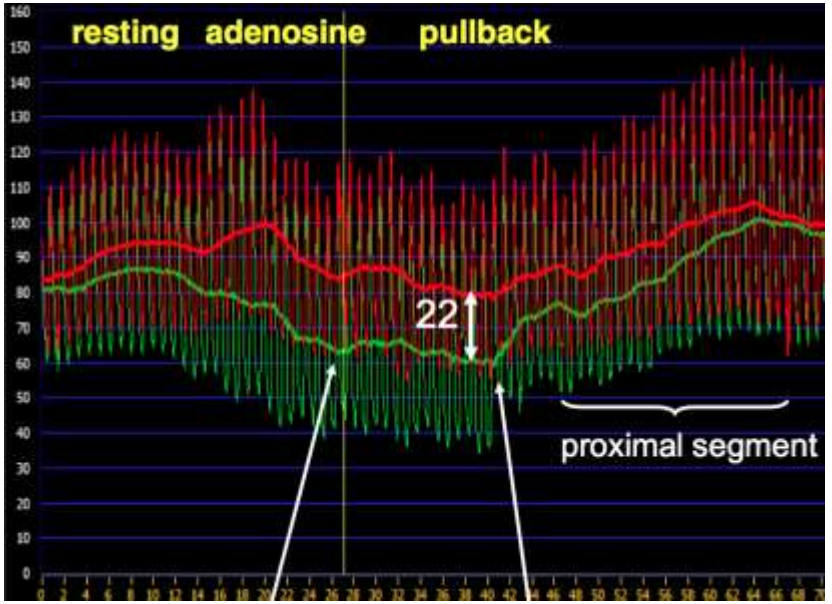
Diffuse disease
Atretic LIMA
@ 4 months

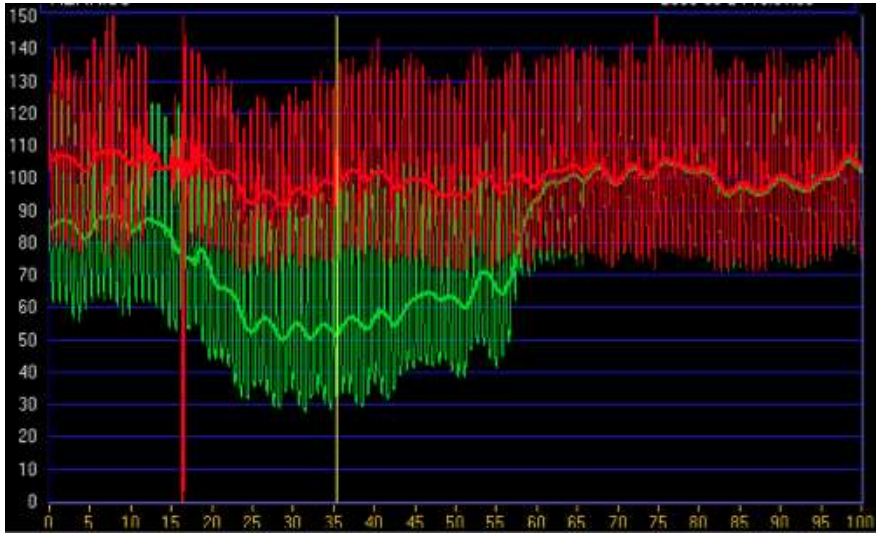
7% versus 21%

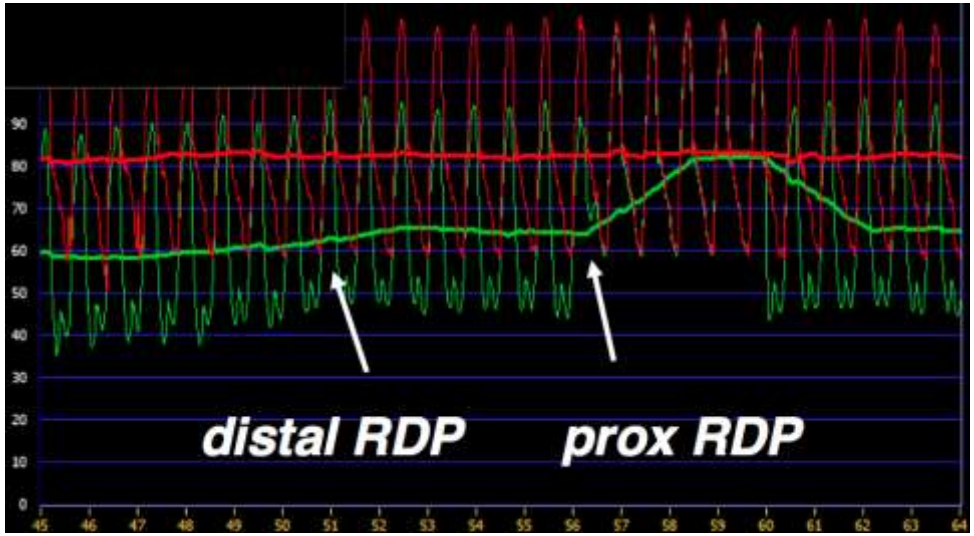
Shiono Y, *Int J Cardiol*. 2016 Nov 1;222:16-21. (Figures 1-3 with colored annotations)

Pullback information #3: *focal*



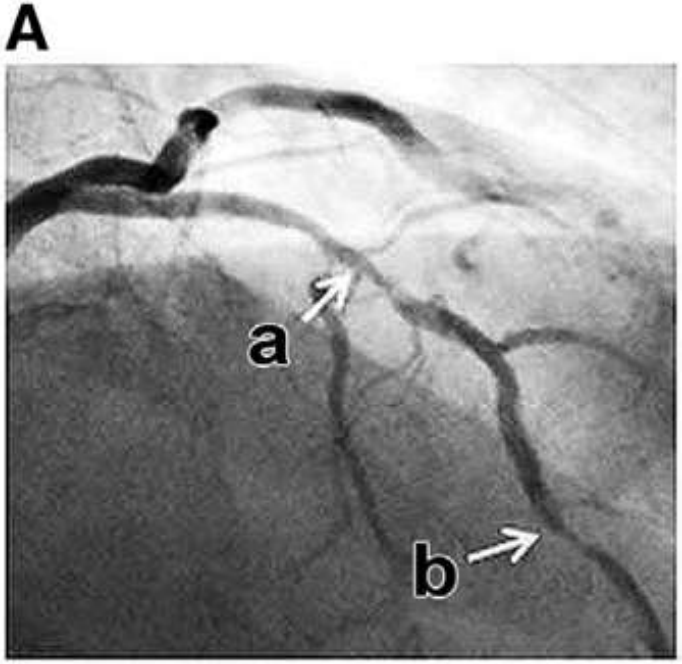






Various pressure tracings from ETP and TCT presentations (De Bruyne, Pijls, Tonino)

Serial/tandem stenoses



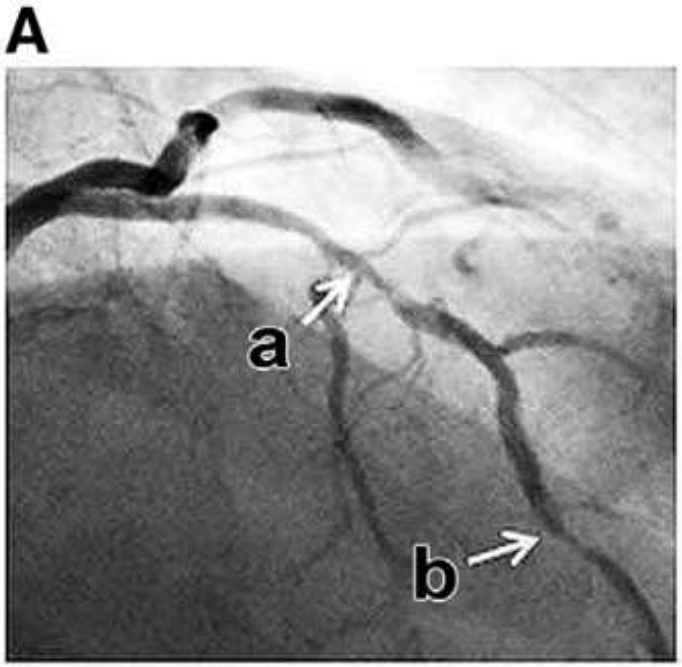
Treat A?

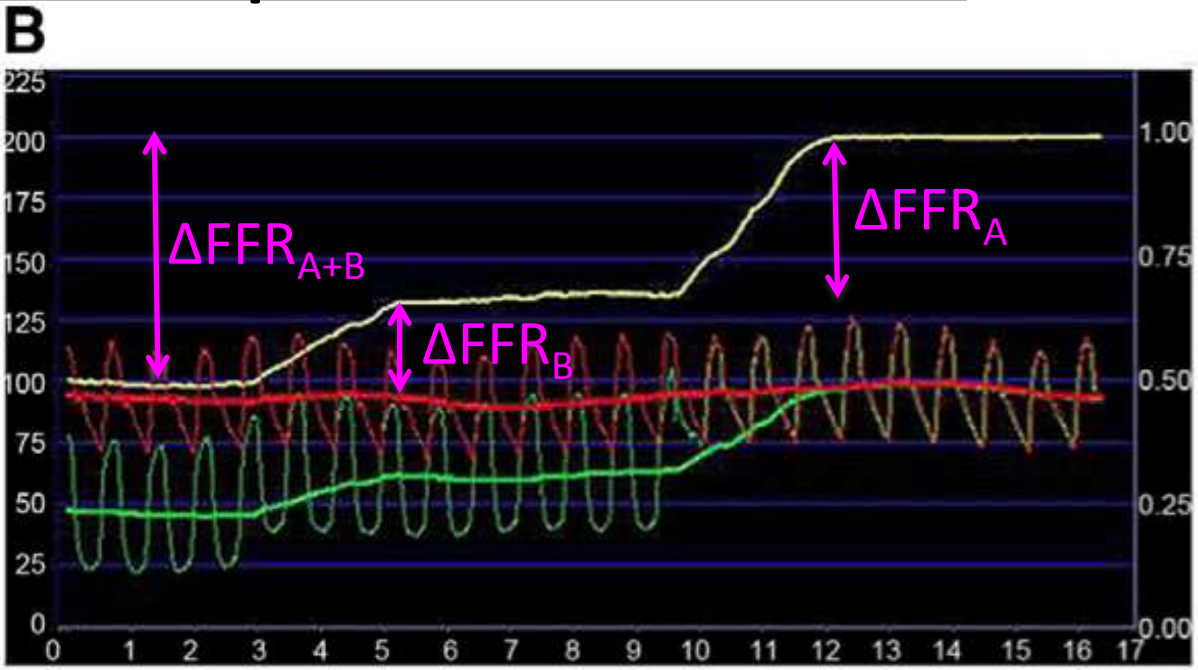
or Treat B?

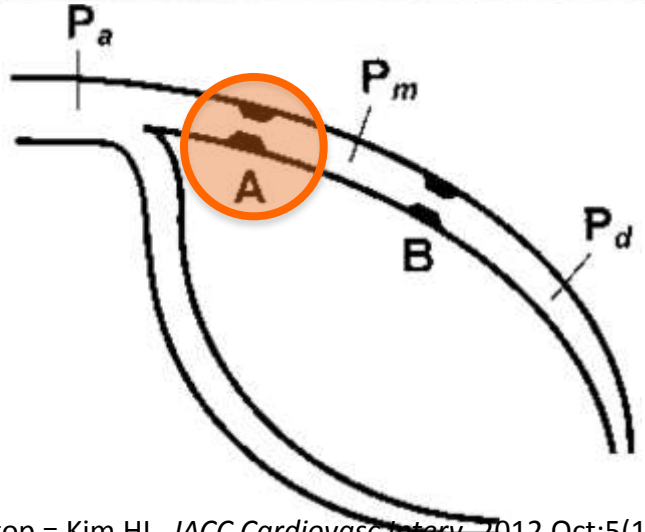
Treat A *and* B?

Kim HL. *JACC Cardiovasc Interv*. 2012 Oct;5(10):1013-8. (Figure 1 A)

Two lesions on pull-back curve



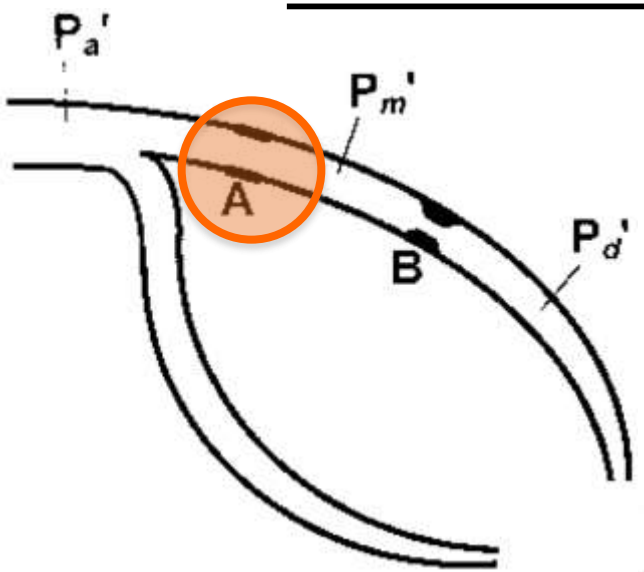




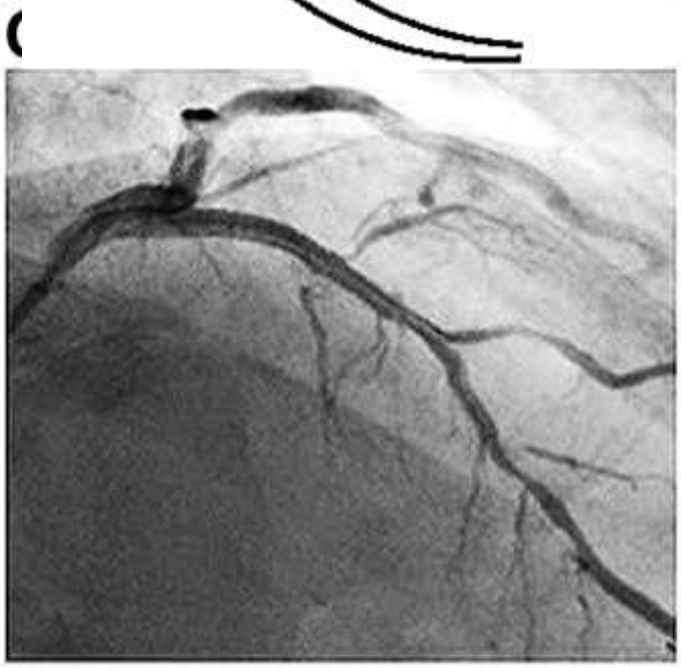
$\Delta FFR_A > \Delta FFR_B$

top = Kim HL. *JACC Cardiovasc Interv*. 2012 Oct;5(10):1013-8. (Figure 1 A and B, annotated)
bottom = Pijls NH. *Circulation*. 2000 Nov 7;102(19):2371-7. (Portions of Figure 2)

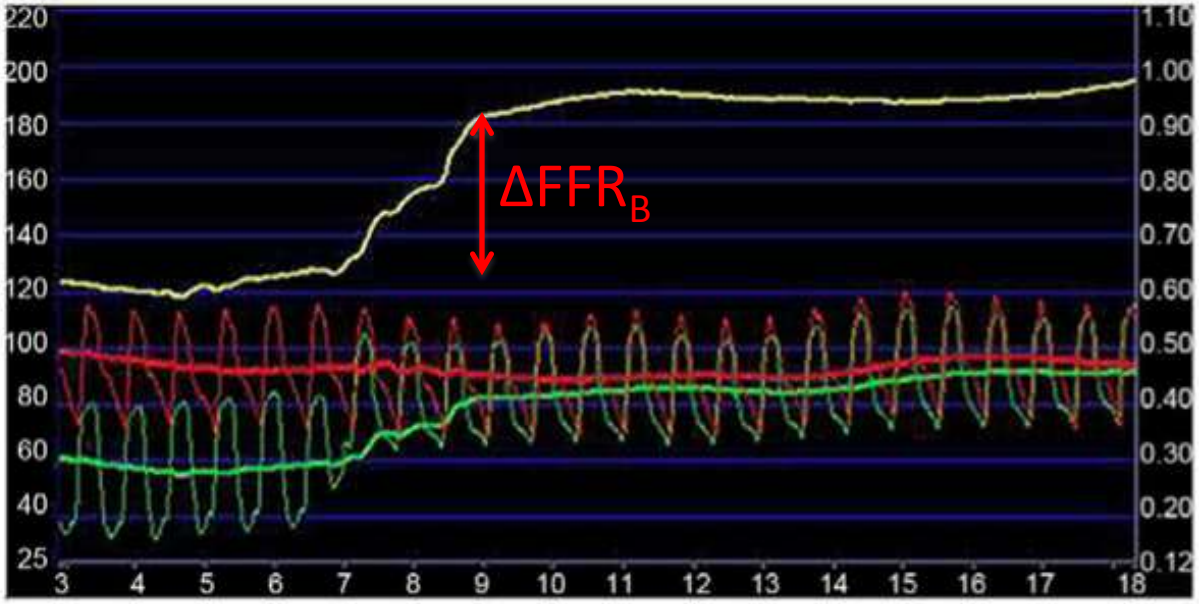
Treat worst and remeasure



$\Delta FFR_A \approx 0$
(good PCI)

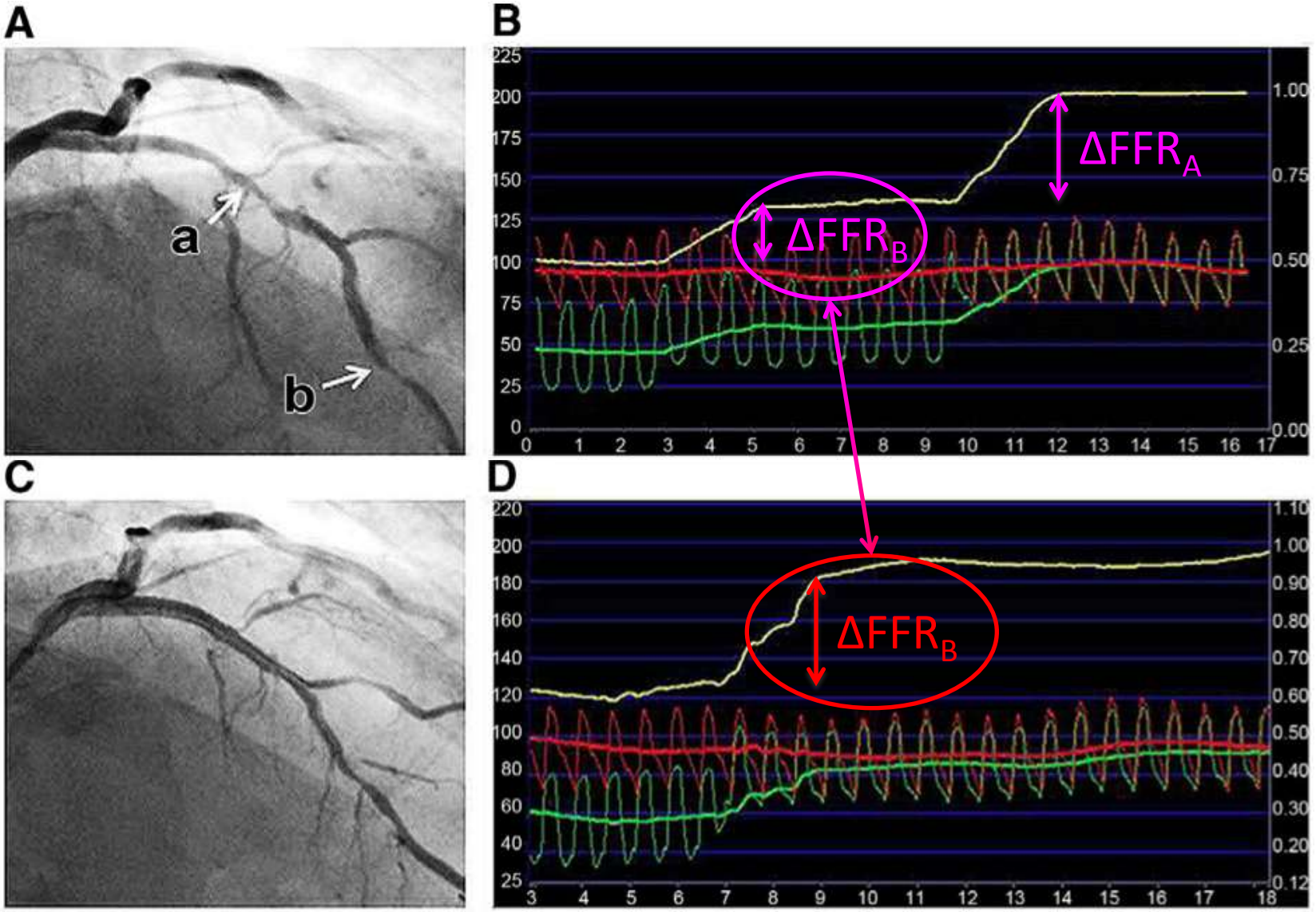


D



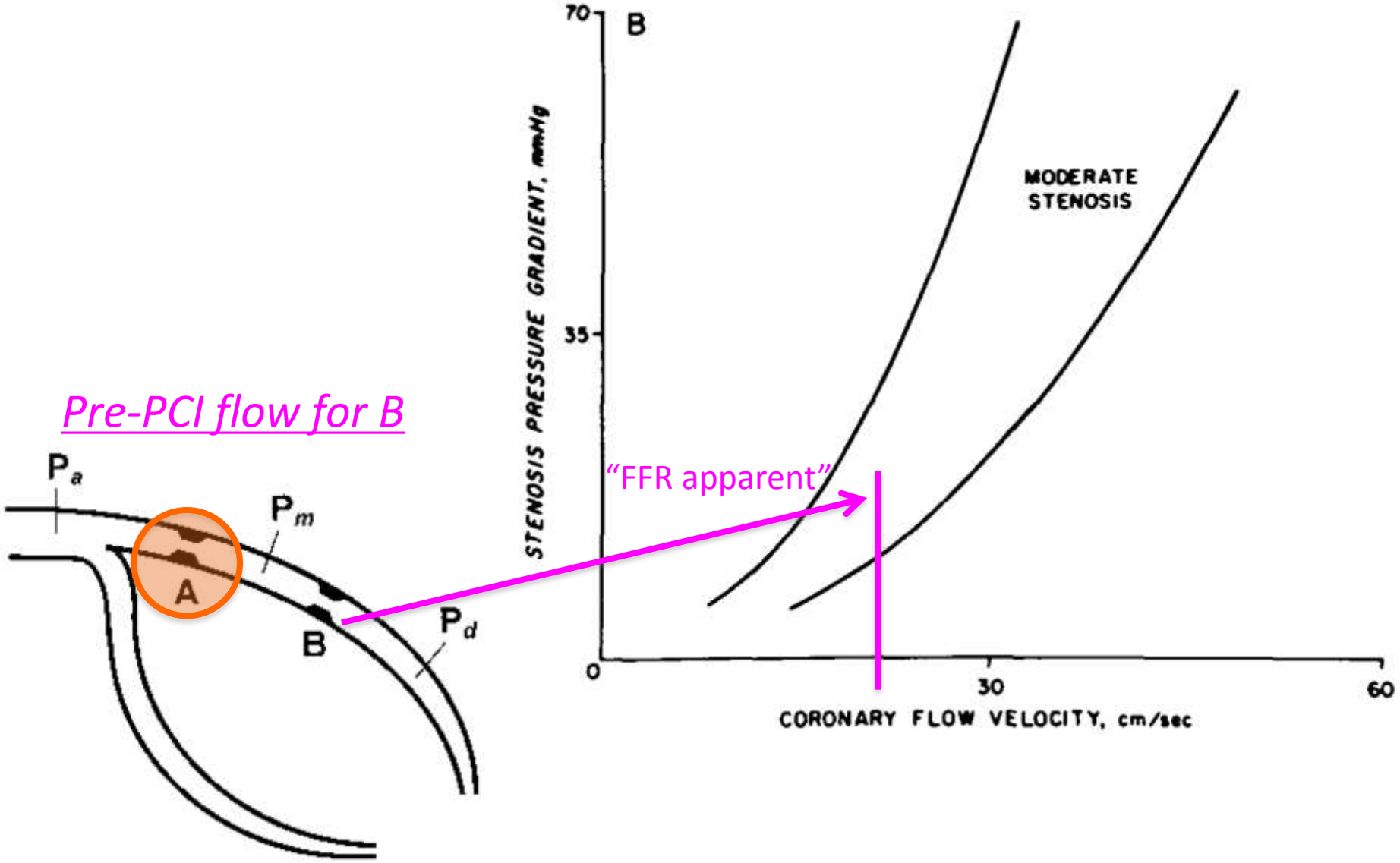
top = Pijls NH. *Circulation*. 2000 Nov 7;102(19):2371-7. (Portions of Figure 2)
bottom = Kim HL. *JACC Cardiovasc Interv*. 2012 Oct;5(10):1013-8. (Figure 1 C and D, annotated)

Why is there “cross talk”?

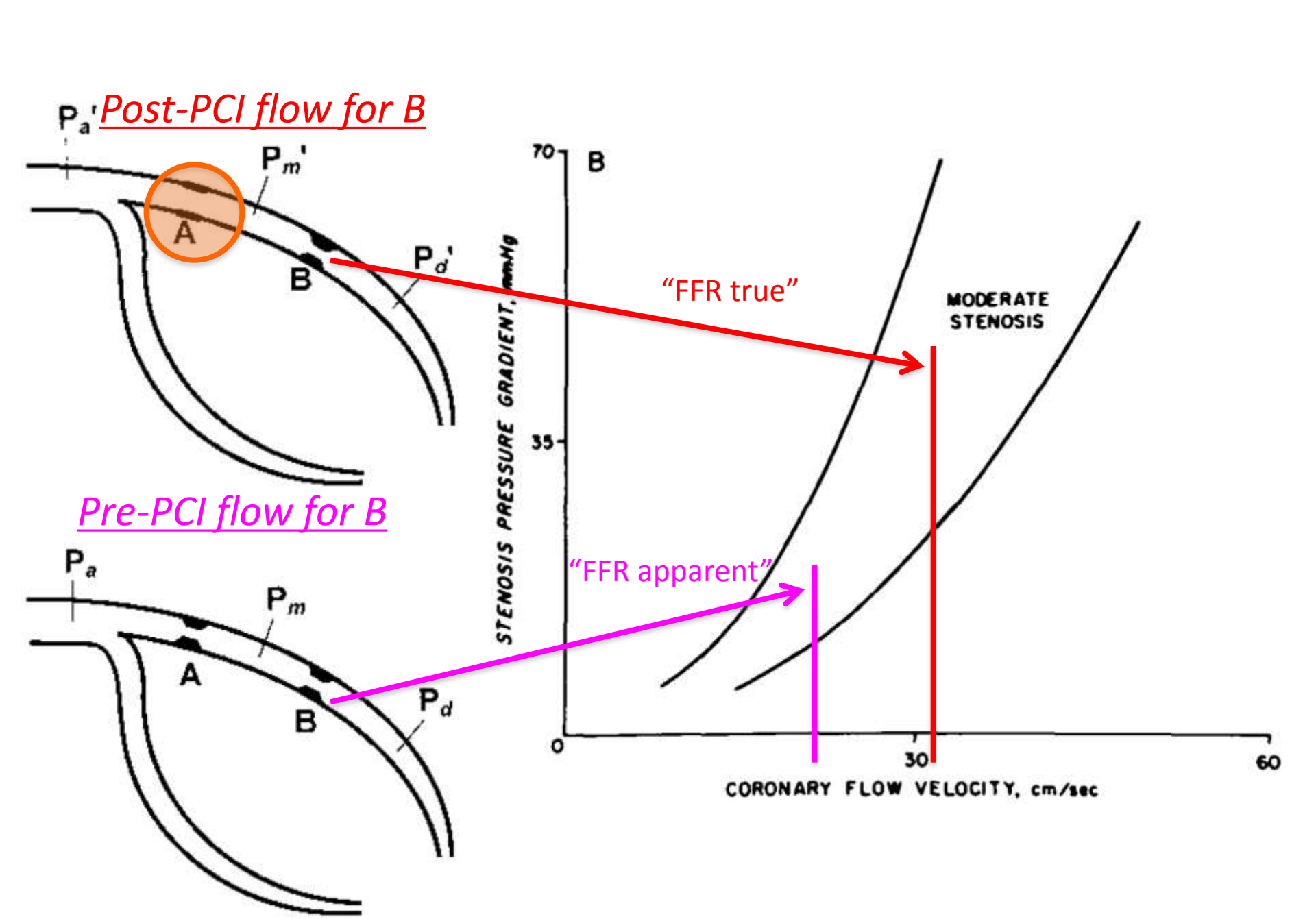


Kim HL. *JACC Cardiovasc Interv*. 2012 Oct;5(10):1013-8. (Figure 1 A to D, annotated)

Why is there "cross talk"?

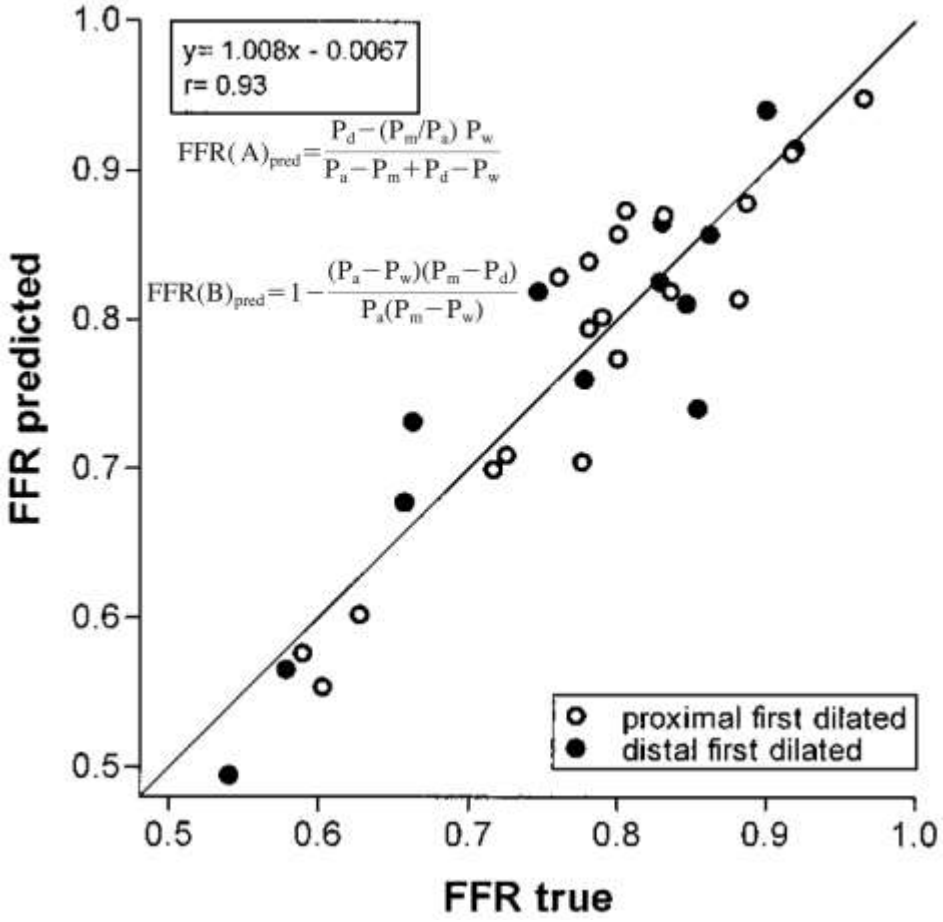


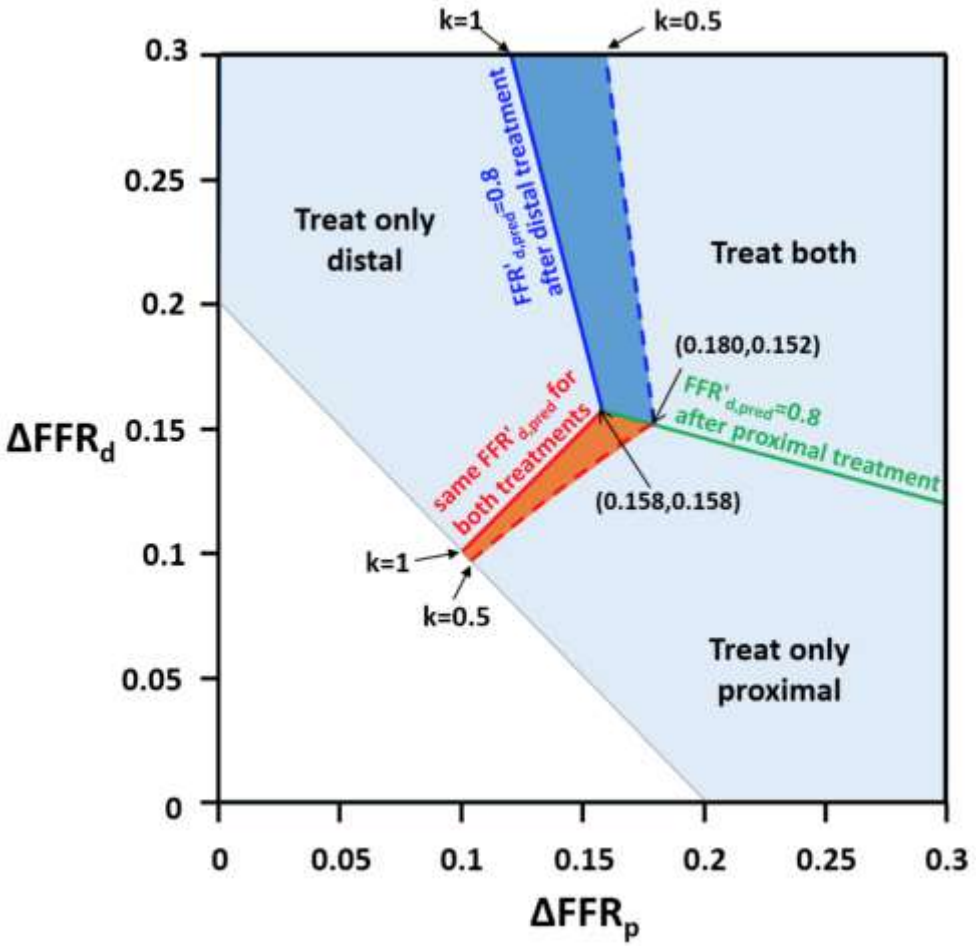
Pijls NH. *Circulation*. 2000 Nov 7;102(19):2371-7. (Portions of Figure 2)
Gould KL. *Circ Res*. 1978 Aug;43(2):242-53. (Figure 8, modified)



Pijls NH. *Circulation*. 2000 Nov 7;102(19):2371-7. (Portions of Figure 2)
Gould KL. *Circ Res*. 1978 Aug;43(2):242-53. (Figure 8, modified)

Can we predict?



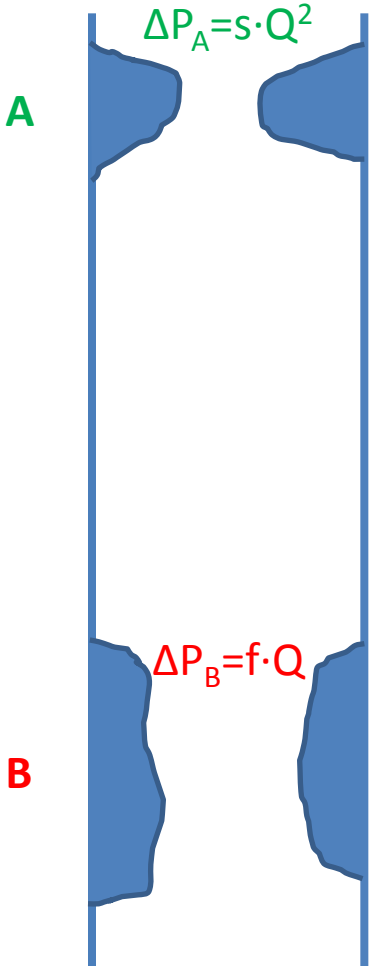


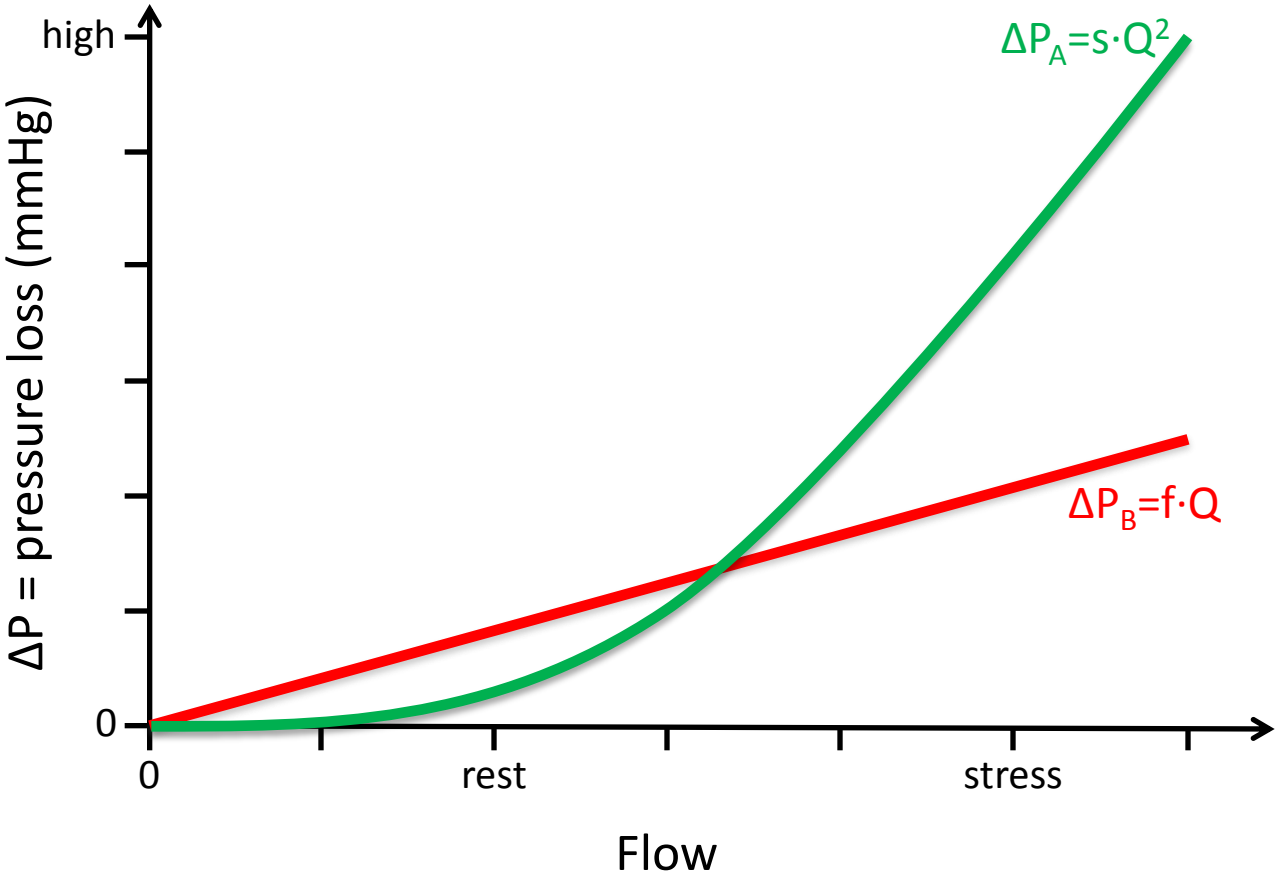
left, graph = Pijls NH. *Circulation*. 2000 Nov 7;102(19):2371-7. (Figure 5B)
left, euqations = De Bruyne B. *Circulation*. 2000 Apr 18;101(15):1840-7. (Equations 3 and 4)
right = Kweon J, *EuroIntervention*. 2016 Nov 22. [Epub ahead of print] (Figure 6)

Limitations to prediction

- Produces false positives and negatives
- Requires measurement of wedge pressure
- Theory makes several assumptions
  - ✓ Neglects quadratic flow term
  - ✓ Does not allow branch between lesions
  - ✓ Assumes no coupling of flow profiles
  - ✓ Venous pressure ignored

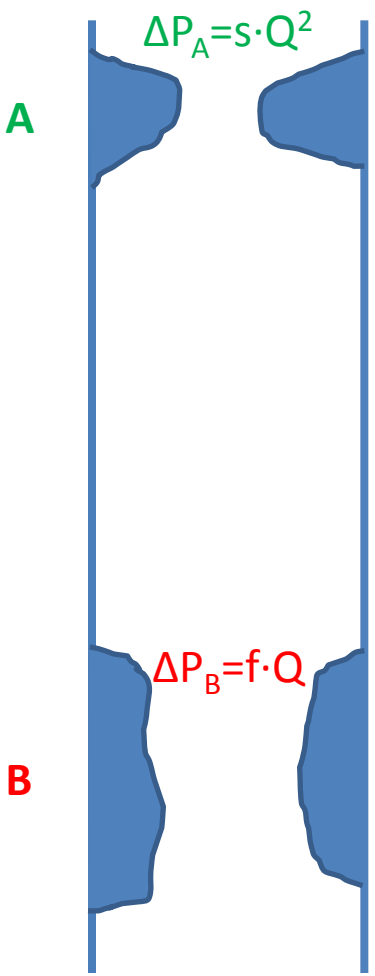
Does resting physiology help?

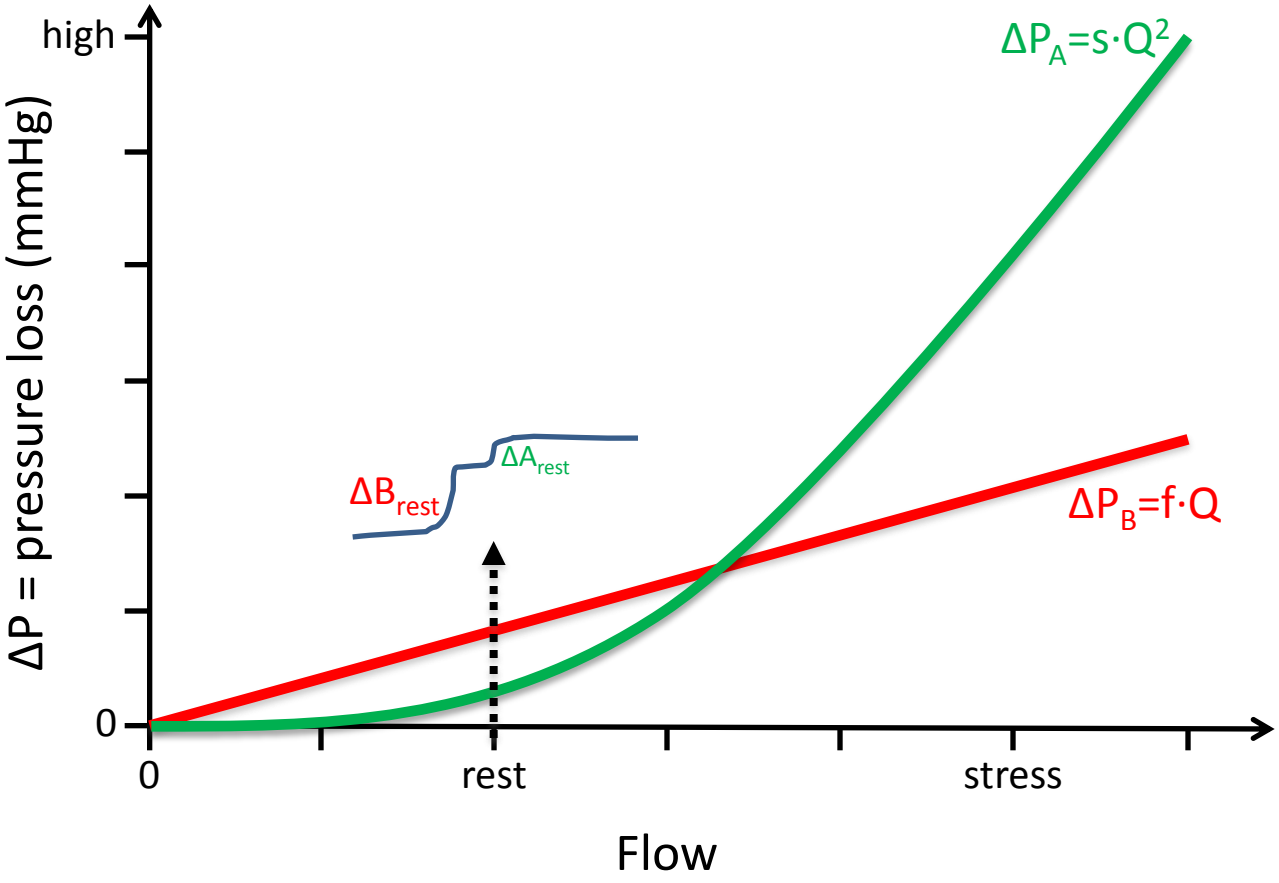




Inspired by discussion with Frederick Zimmermann, February 24, 2017.

Does resting physiology help?

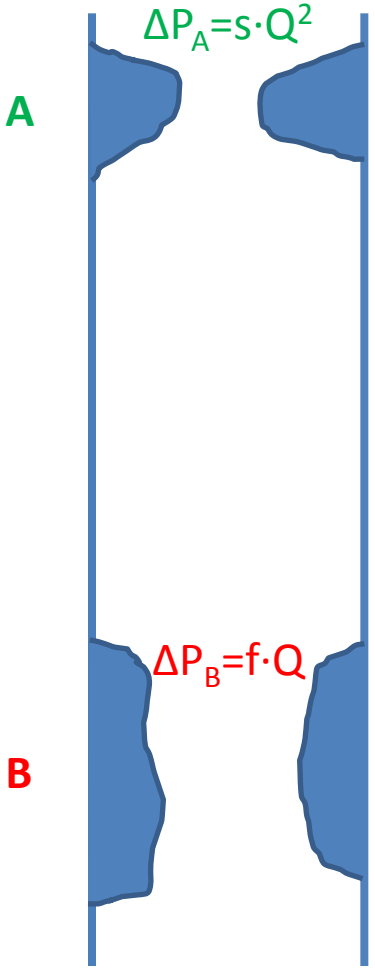


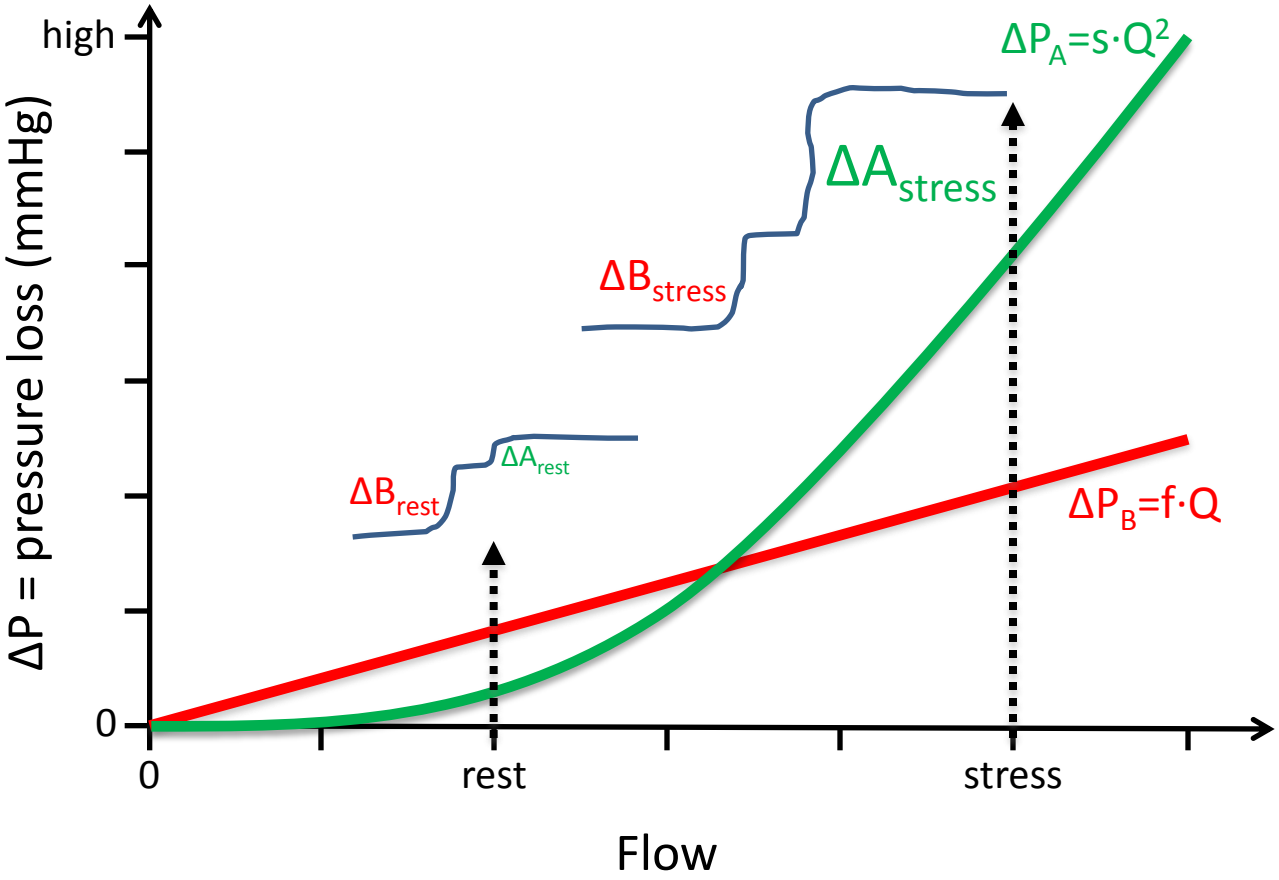


Rest conclusion: B worse than A

Inspired by discussion with Frederick Zimmermann, February 24, 2017.

Does resting physiology help?

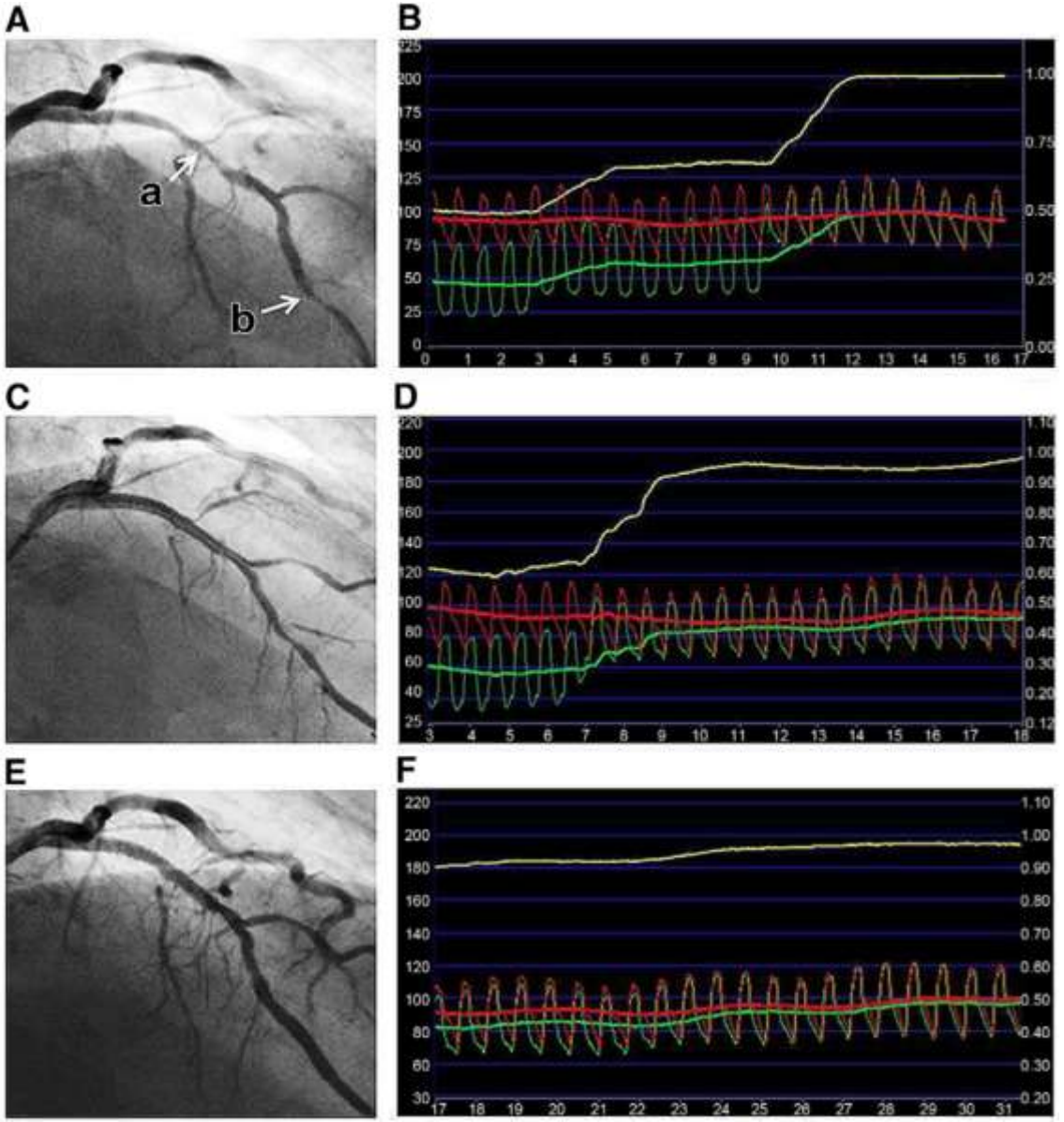




Stress conclusion: A worse than B
(also easier to measure!)

Inspired by discussion with Frederick Zimmermann, February 24, 2017.

“Everyday” algorithm for serial lesions



pullback

treat worst (if possible) and remeasure (>>distal PCI 1st)

stop when significant focal (Δ>10mmHg) is gone

Kim HL. *JACC Cardiovasc Interv*. 2012 Oct;5(10):1013-8. (Figure 1)

But what about the left main?

benchtop, 2012

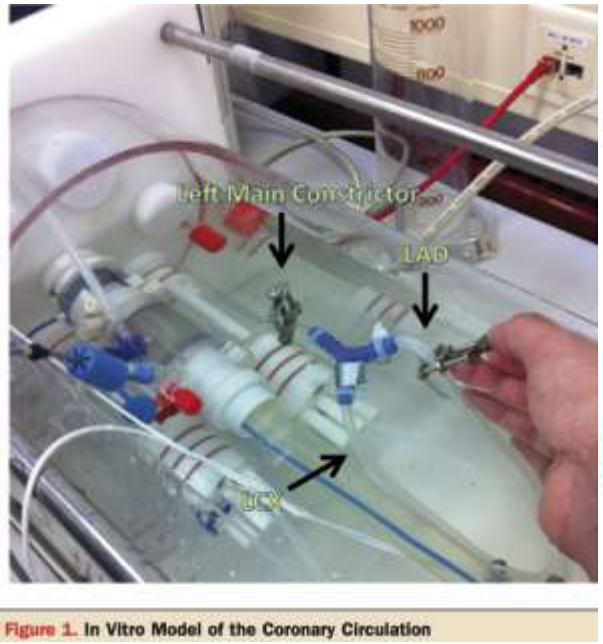
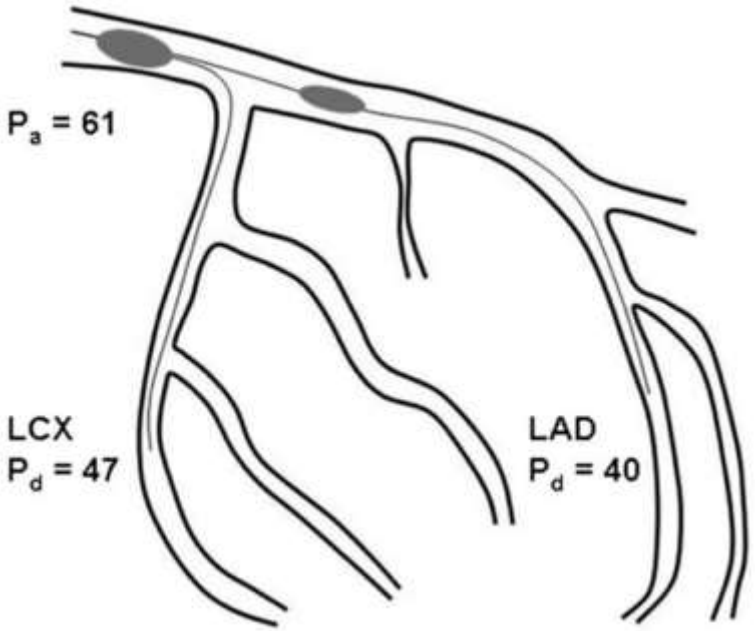
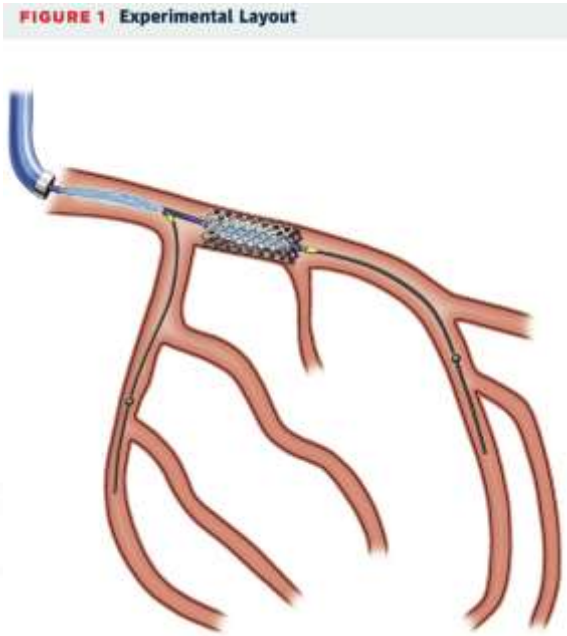


Figure 1. In Vitro Model of the Coronary Circulation

animals, 2013



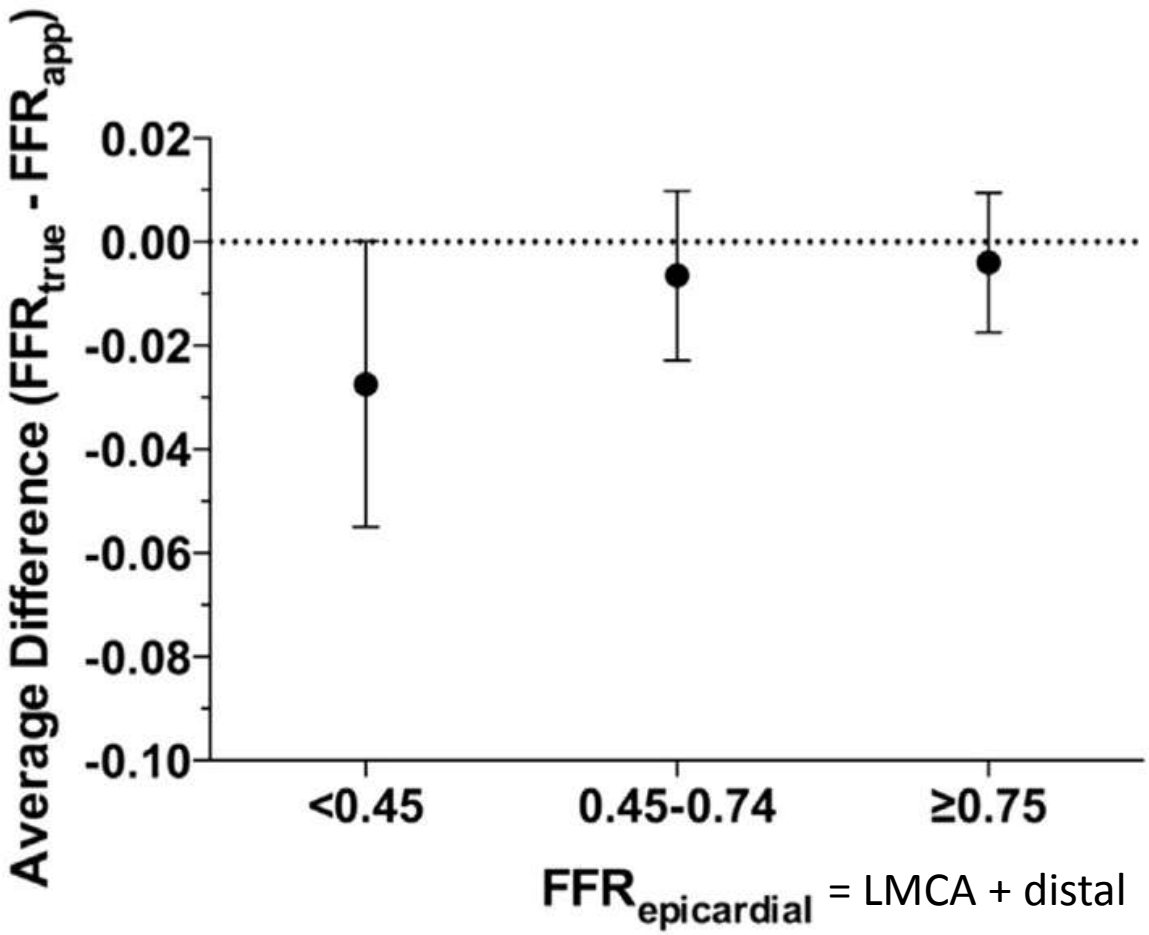
humans, 2015



left = Daniels DV. *JACC Cardiovasc Interv*. 2012 Oct;5(10):1021-5. (Figure 1)
middle = Yong AS. *Circ Cardiovasc Interv*. 2013 Apr;6(2):161-5. (Figure 1B)
right = Fearon WF. *JACC Cardiovasc Interv*. 2015 Mar;8(3):398-403. (Figure 1)

Only important with low distal FFR

FIGURE 7 Minimal Effect of Downstream Disease on LMCA FFR



Fearon WF. *JACC Cardiovasc Interv*. 2015 Mar;8(3):398-403. (Figure 7)

Algorithm for LM serial/tandem lesion

- Measure FFR in LMCA + non-diseased vessel
  - ✓ FFR≤0.80 then LMCA significant
  - ✓ FFR>0.85 then LMCA not significant
  - ✓ FFR=0.81 to 0.85
    - Measure FFR = LMCA + diseased vessel
    - If FFR_{distal}≤0.45 then LMCA ?significant
    - If FFR_{distal}>0.45 then LMCA likely OK

Fearon WF. *JACC Cardiovasc Interv*. 2015 Mar;8(3):398-403. (Clinical implications)

Practice and Potential Pitfalls of Coronary Pressure Measurement

Nico H.J. Pijls,[1]* MD, PhD, Morton J. Kern,[2]† MD, Paul G. Yock,[3]† MD and Bernard De Bruyne[4] MD, PhD

In summary, a pullback curve at maximum hyperemia is the most accurate, most convincing, and most reliable way to study the functional status of every part of a coronary artery. The pullback curve under hyperemia never lies.

Pijls NH, *Catheter Cardiovasc Interv*. 2000 Jan;49(1):1-16. (Text excerpts)