Imaging & Physiology Summit

A New Avenue to The Coronary Microcirculation: Absolute Flow And Resistance Measurement by The Pressure Wire

Seoul, Korea, december 3rd, 2015

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A NEW AVENUE TO THE CORONARY MICROCIRCULATION

Presently, there is a growing interest in studying the Microcirculation of the heart, but….

- Present invasive techniques to assess the microcirculation, are crude, inaccurate, and extremely operator-dependent

- Doppler: *- inaccuracy of measurement ≥ 20%*
  - adequate signals in ≤ 70% of patients
  - signal extremely operator-dependent

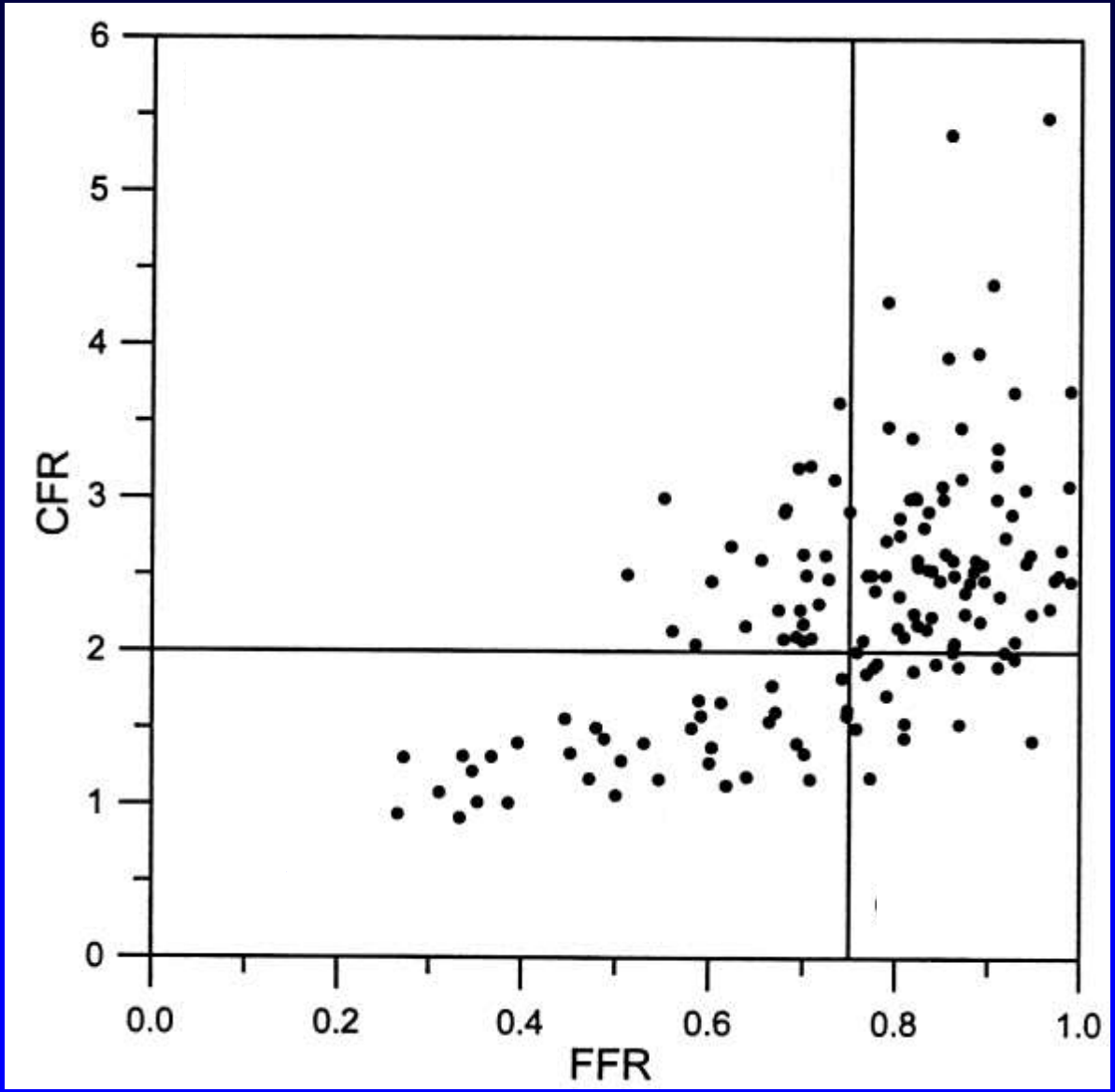
- IMR: *- easier to perform*
  - but also inaccuracy of ≥ 15%
  - and also operator-dependent

A NEW AVENUE TO THE CORONARY MICROCIRCULATION

Consequently, a lot of our knowledge about the microcirculation is speculative and open for multiple interpretations

Use of CFR and FFR to classify microvascular disease

150 patients, CFR & FFR measurement



Meeuwissen, Circulation 2001

Use of CFR and FFR to classify microvascular disease

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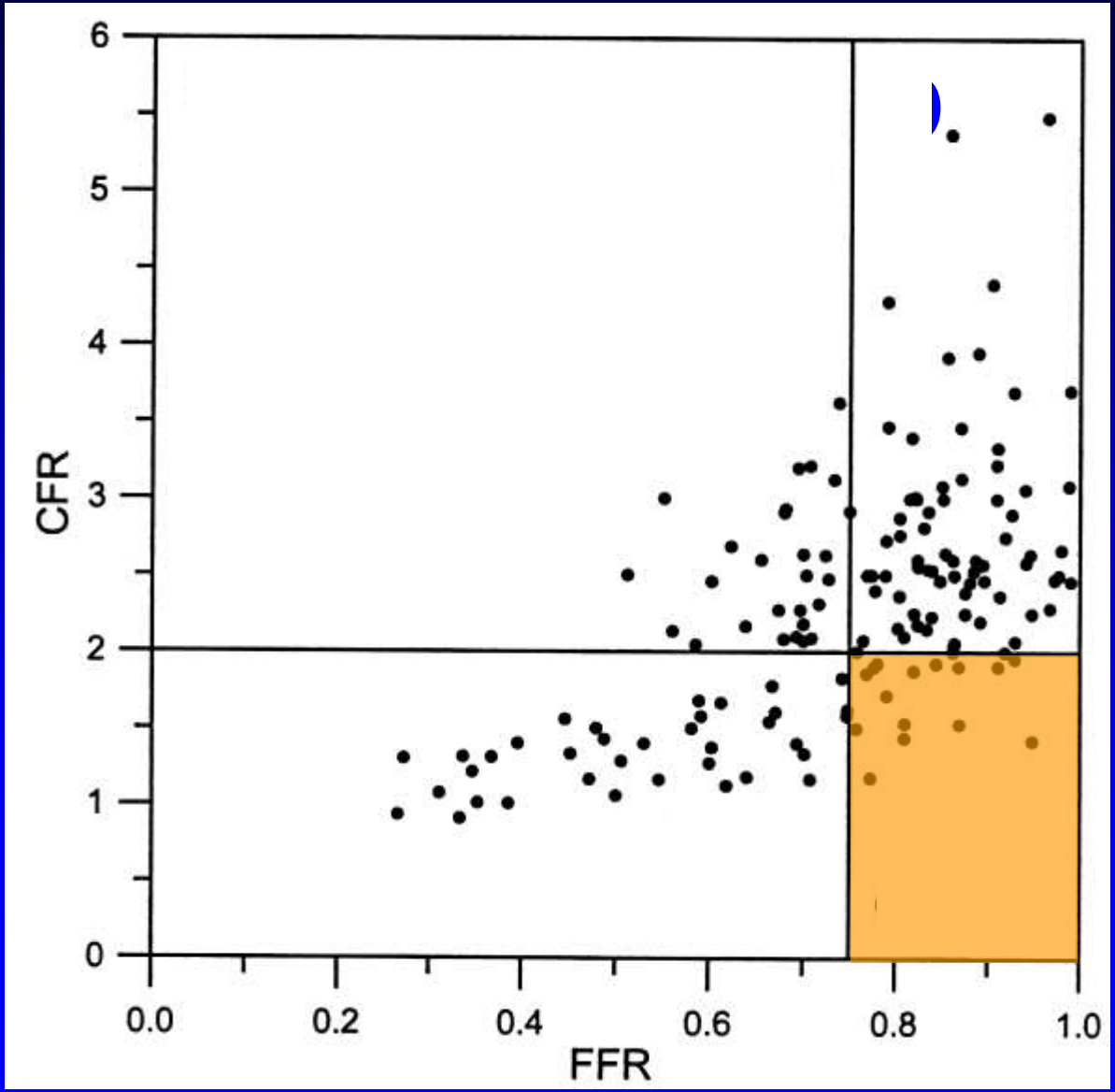

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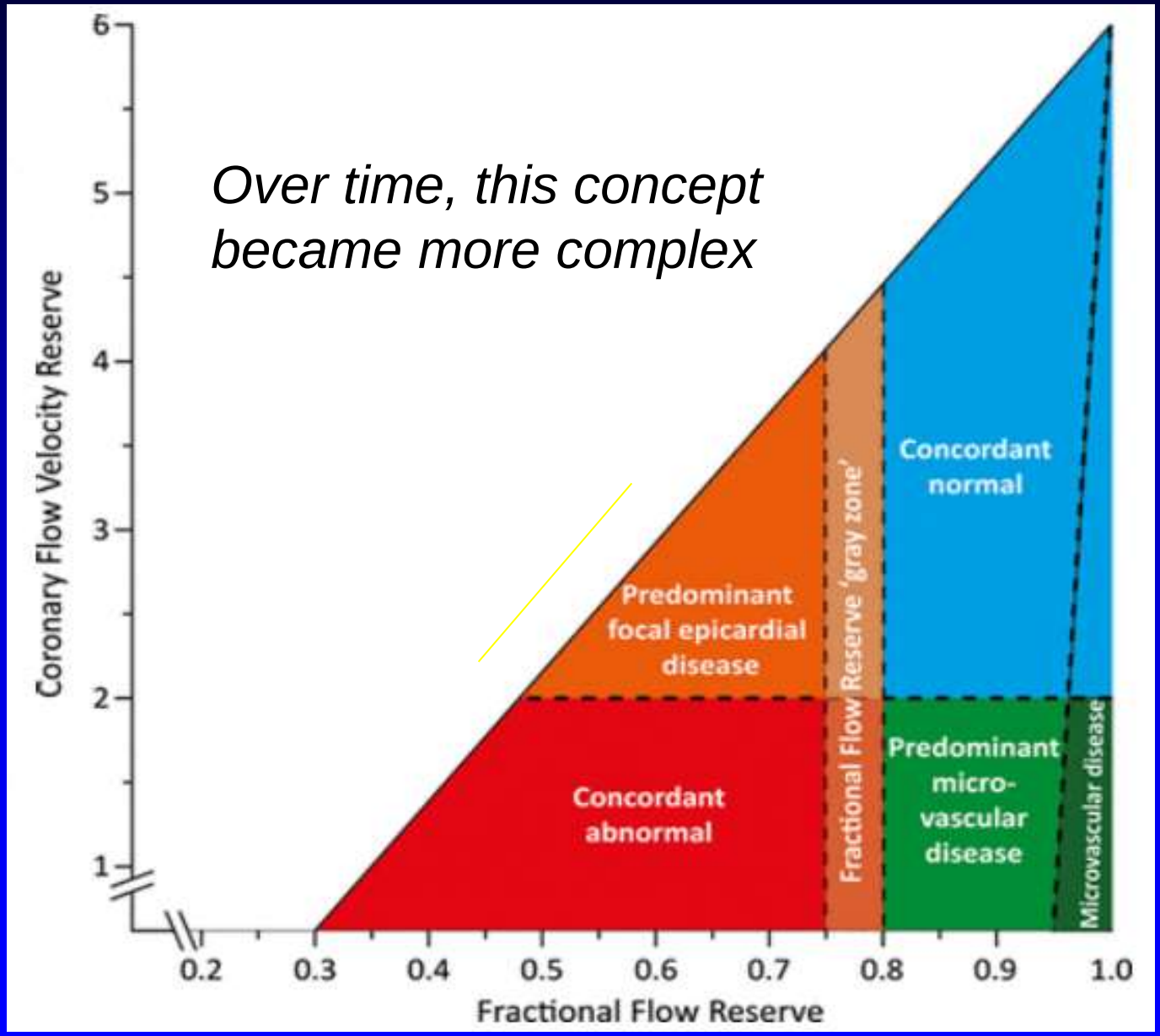
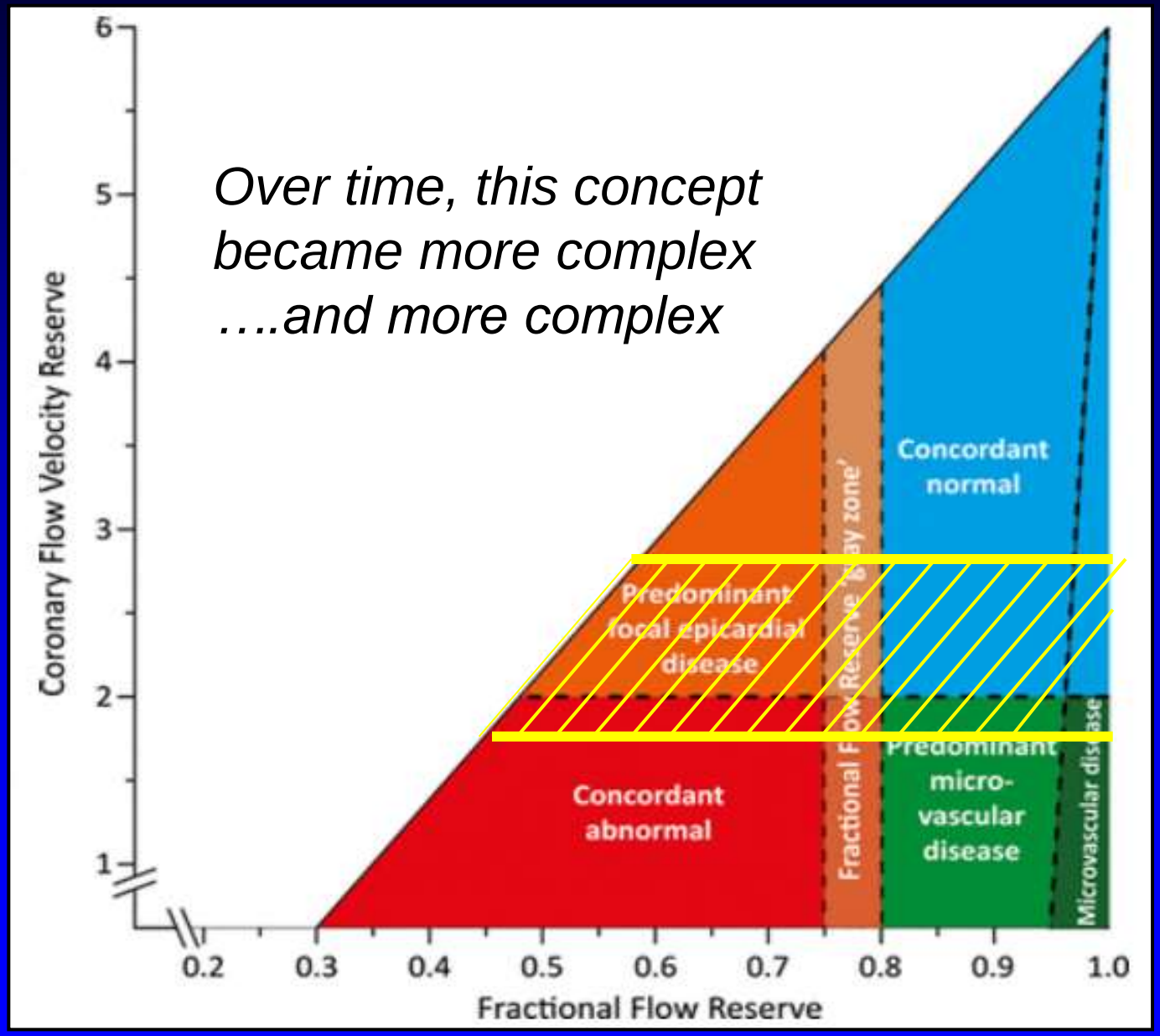
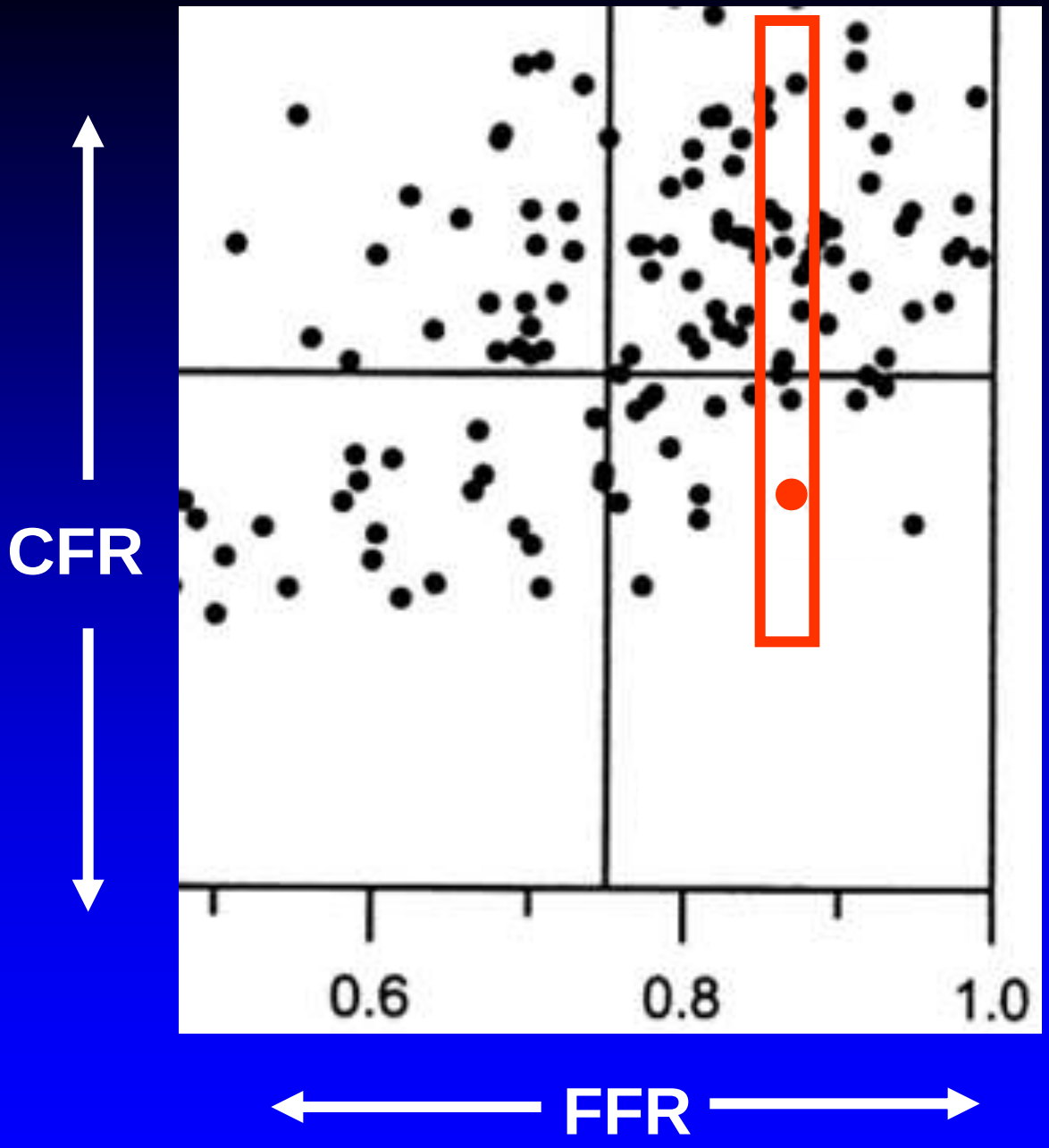
Use of CFR and FFR to classify microvascular disease



Use of CFR and FFR to classify microvascular disease



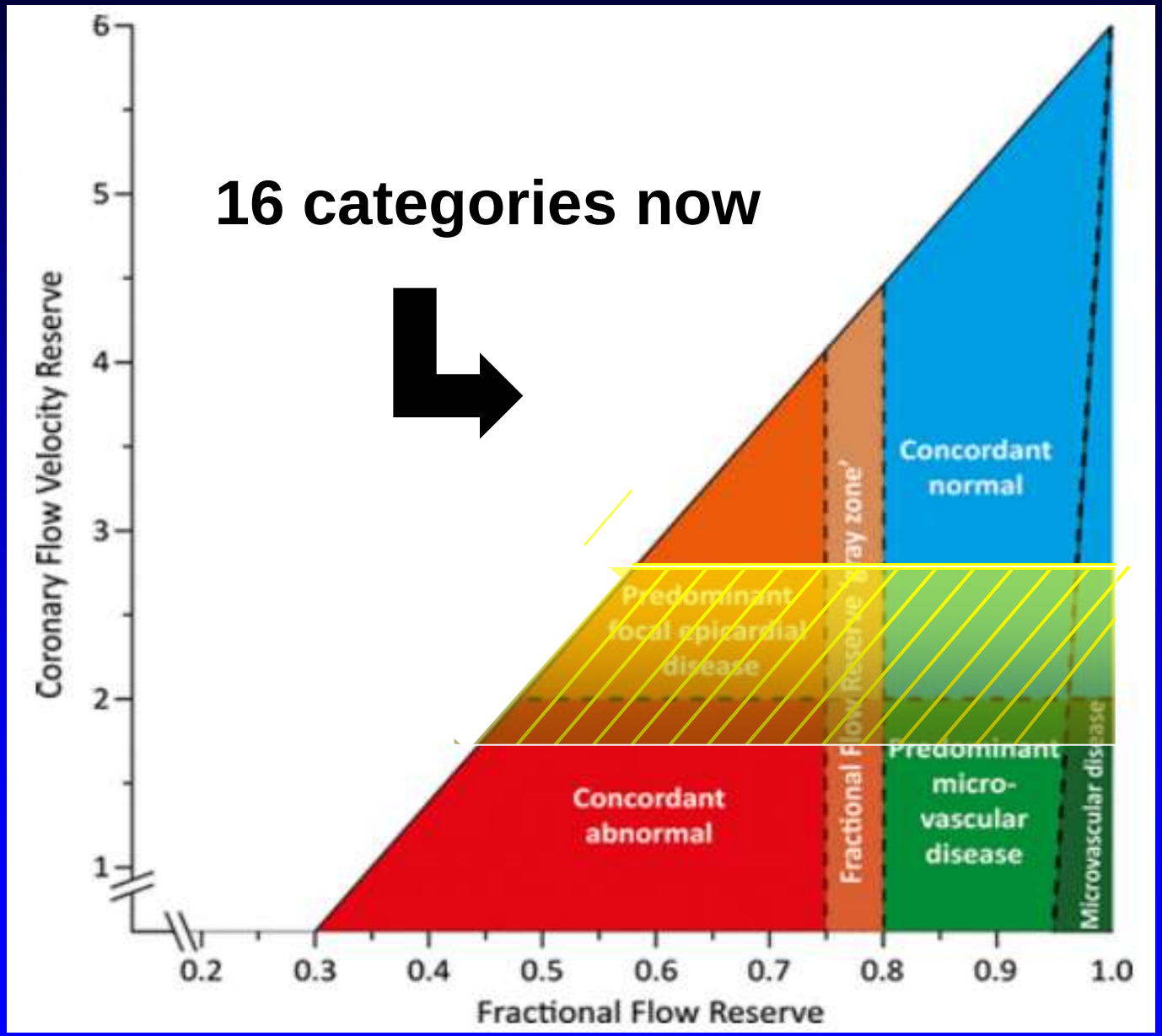


Variability in horizontal direction (***FFR***) = **2 %**

Variability in vertical direction (***CFR***) = **20 %**

No reliable conclusions about microcirculation possible if flow cannot be assessed more accurately !

Use of CFR and FFR to classify microvascular disease



Use of CFR and FFR to classify microvascular disease

Next year, it might look like this……!

A NEW AVENUE TO THE CORONARY MICROCIRCULATION

So it might be clear:

No reliable conclusions about microcirculation are possible if flow cannot be assessed more accurately !

A NEW AVENUE TO THE CORONARY MICROCIRCULATION

The ideal technique to assess the microcirculation, should be:

- easy to perform with standard PCI equipment
- accurate and reproducible
- operator-independent

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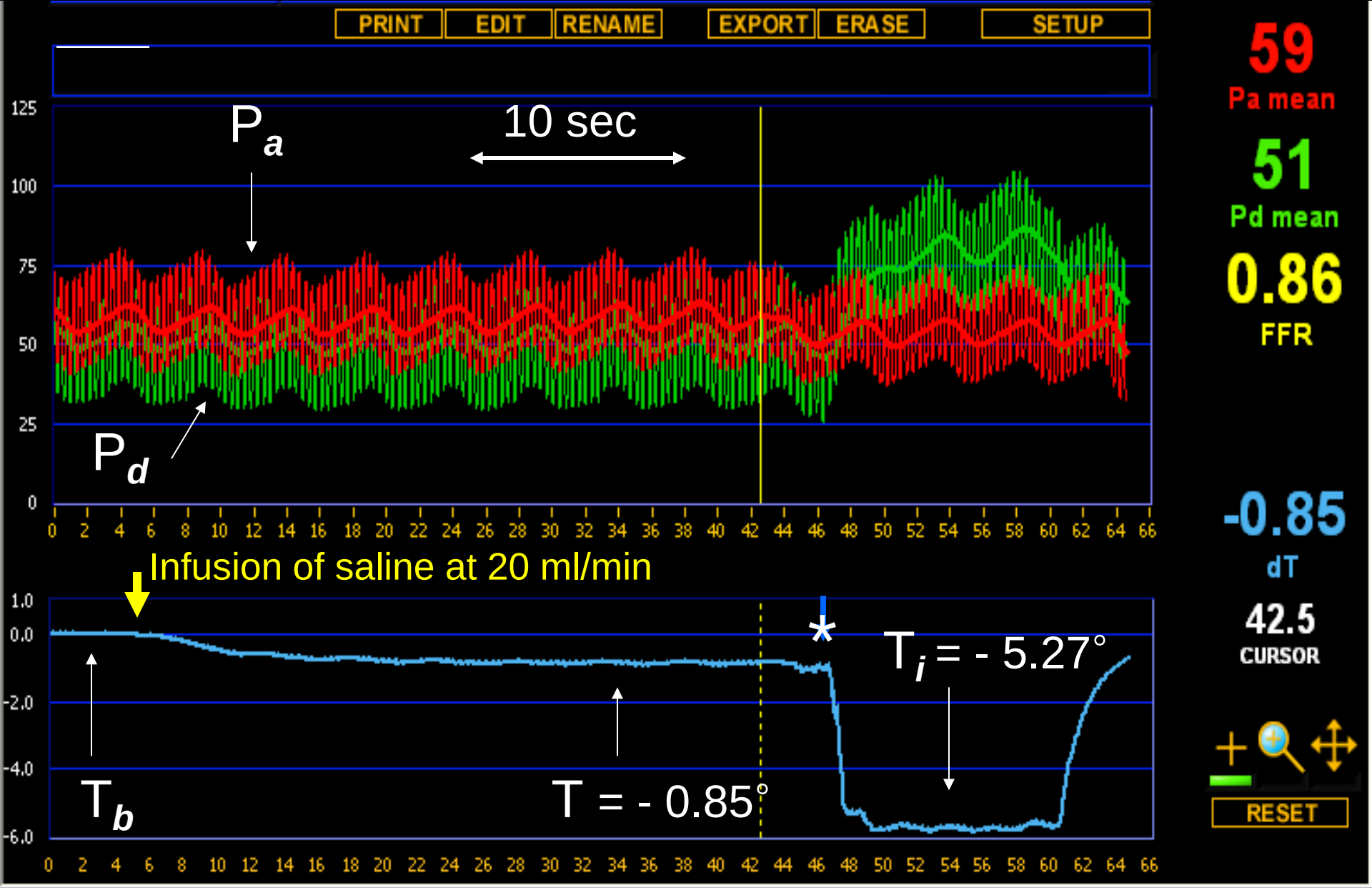
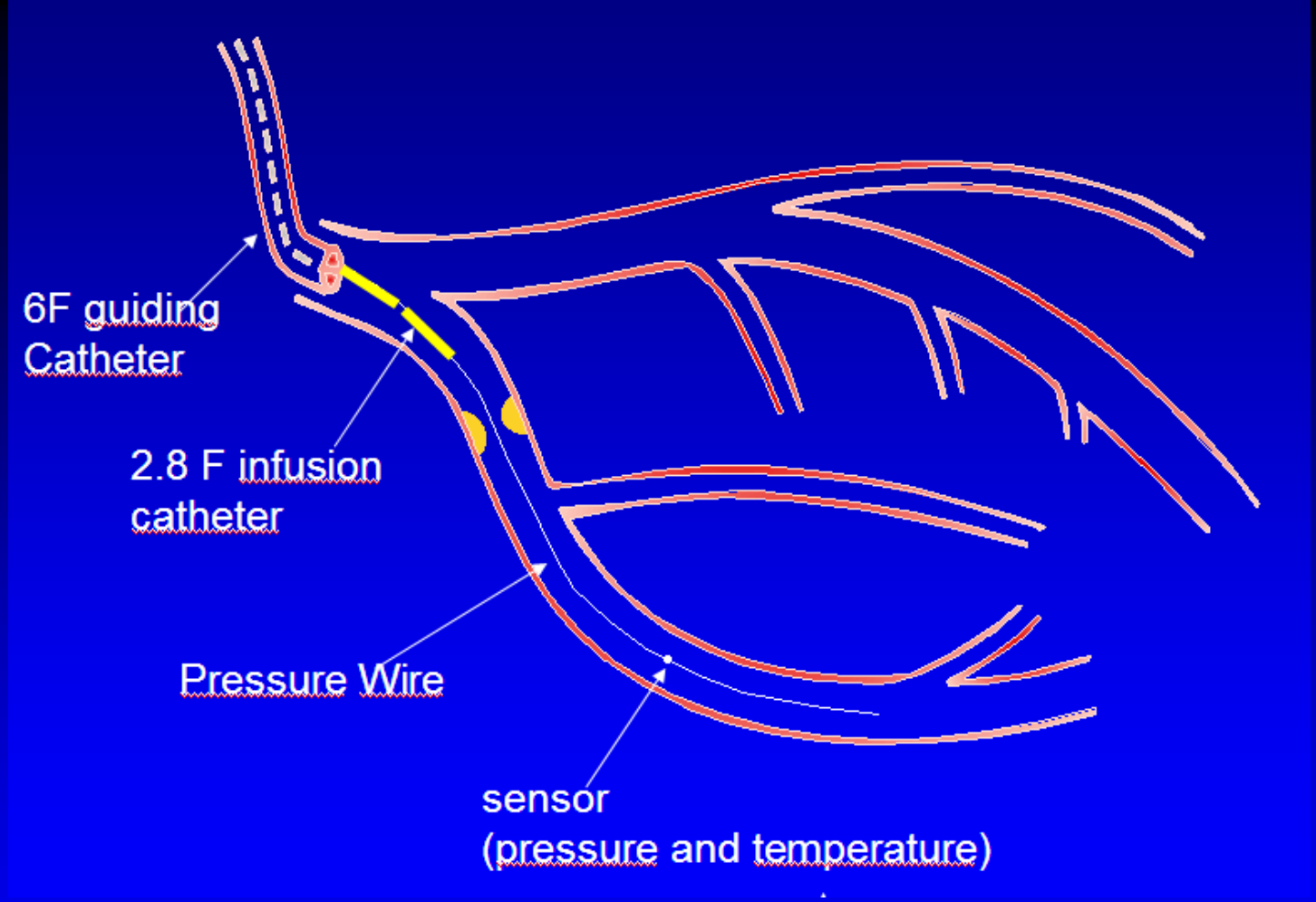
→ *Measurement of absolute flow and resistance by thermodilution and continuous infusion of saline*

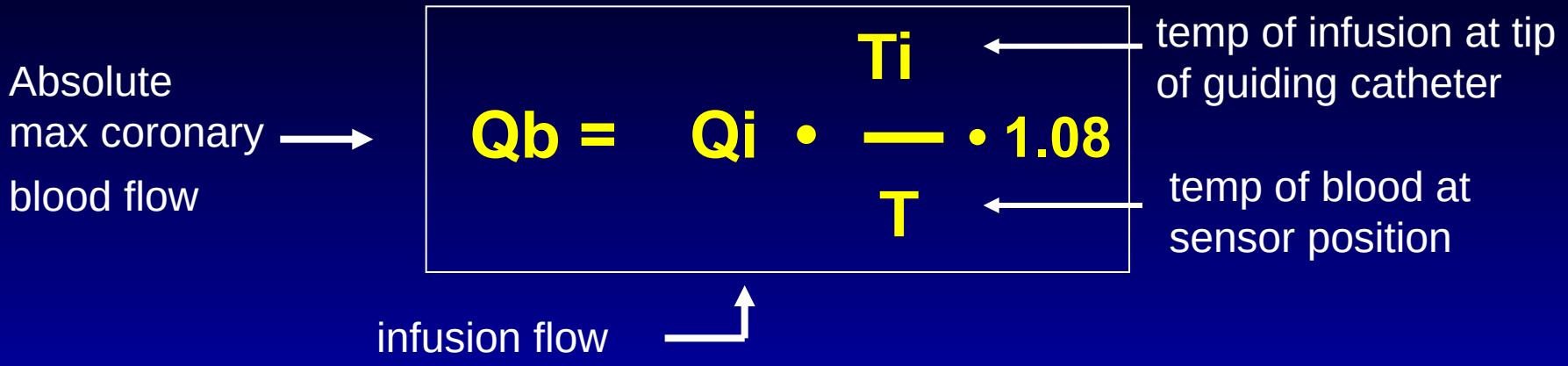


Q*b* = 20 x (-5.27 *I* -0.85) x 1.08 = 134 ml/min



saline infused at 20 ml/min
temperature of saline is 5° below blood temperature
after mixing, temperature of mixtate is 1° below blood temp

→ blood flow must be 5 x infusion flow of saline



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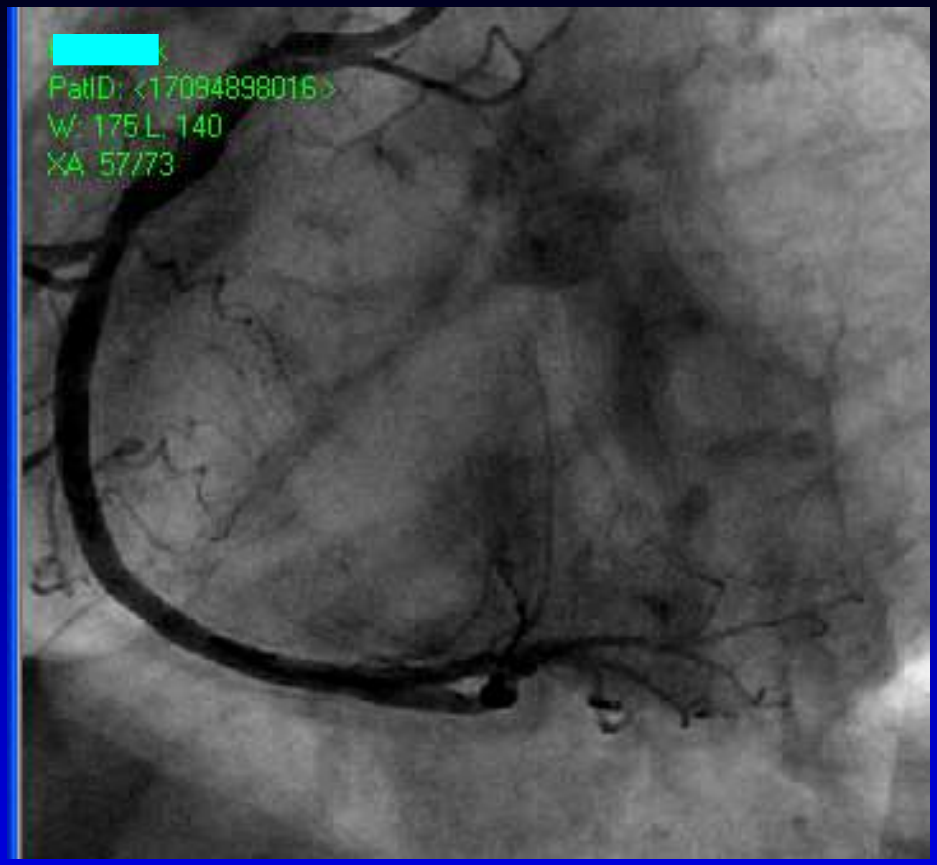
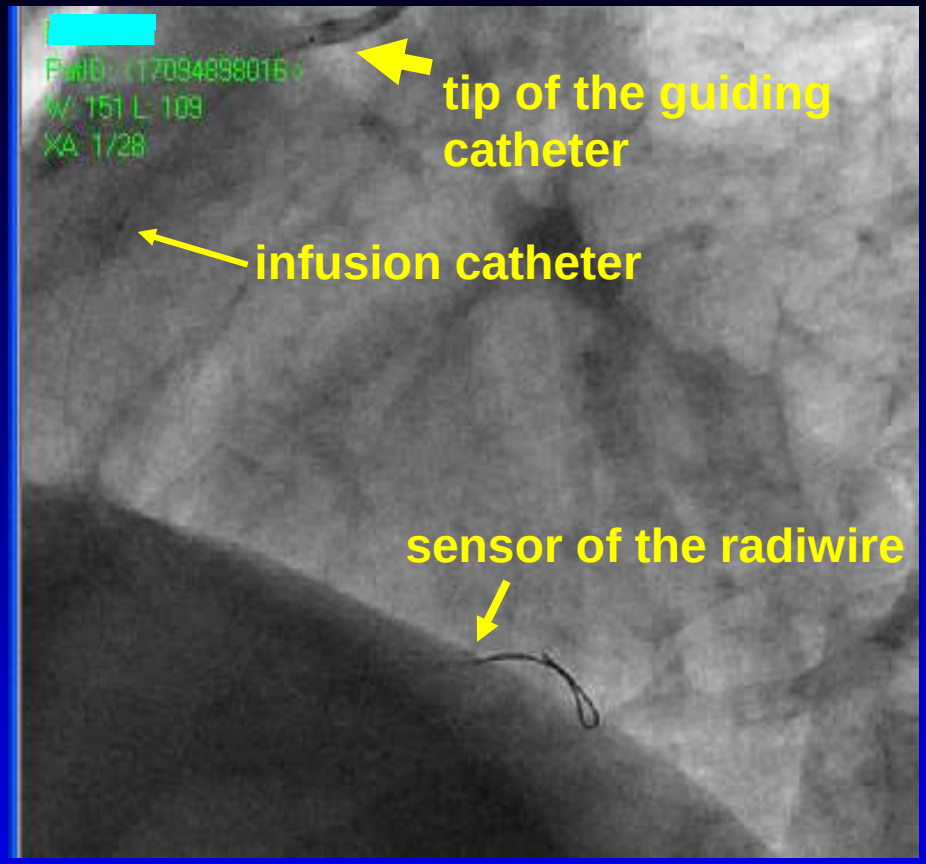
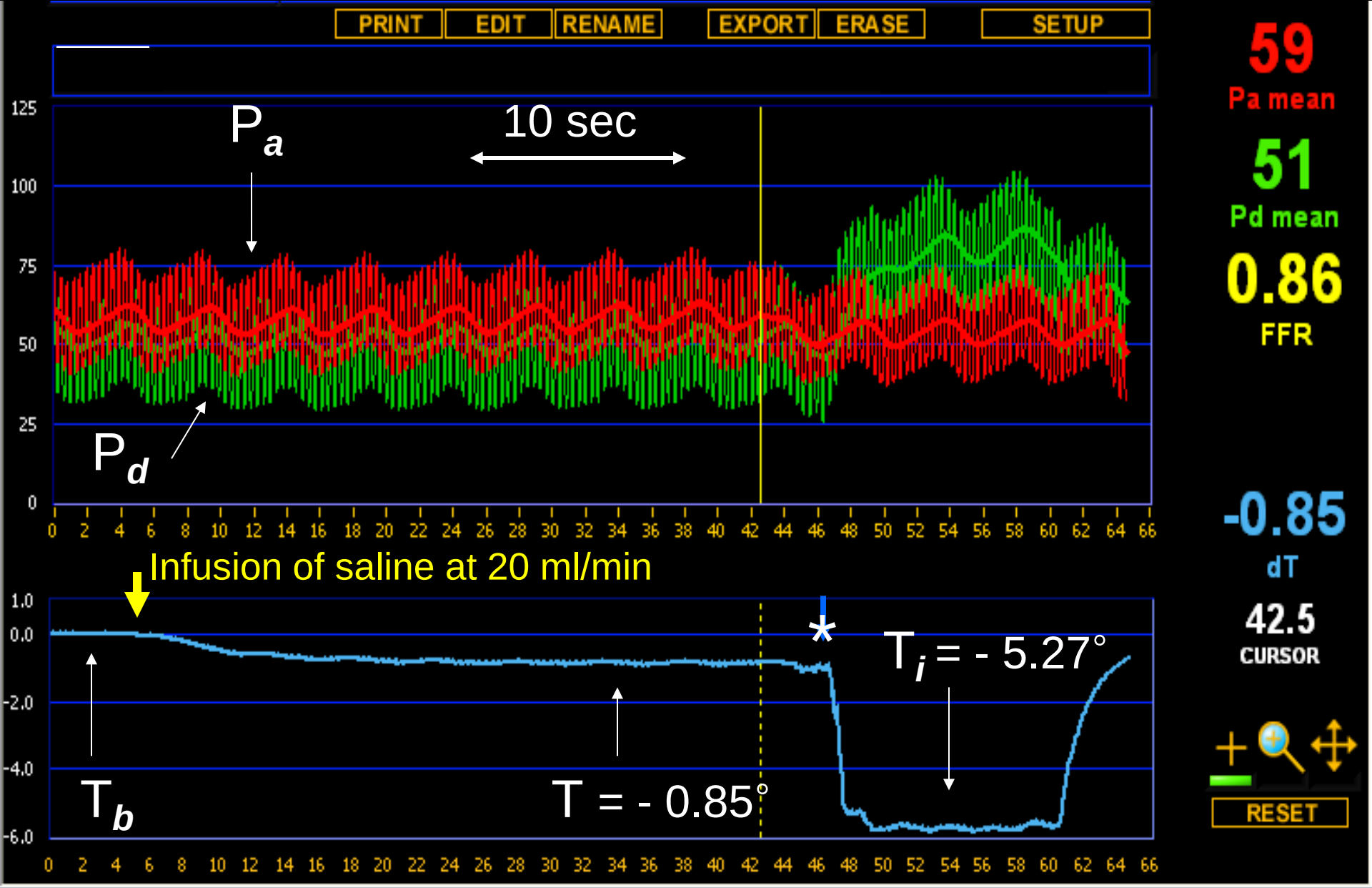

PatID: <17084898016>
W: 175 L: 140
XA 57/73


W: 151 L: 109
XA 1/28
tip of the guiding catheter
infusion catheter
sensor of the radiwire



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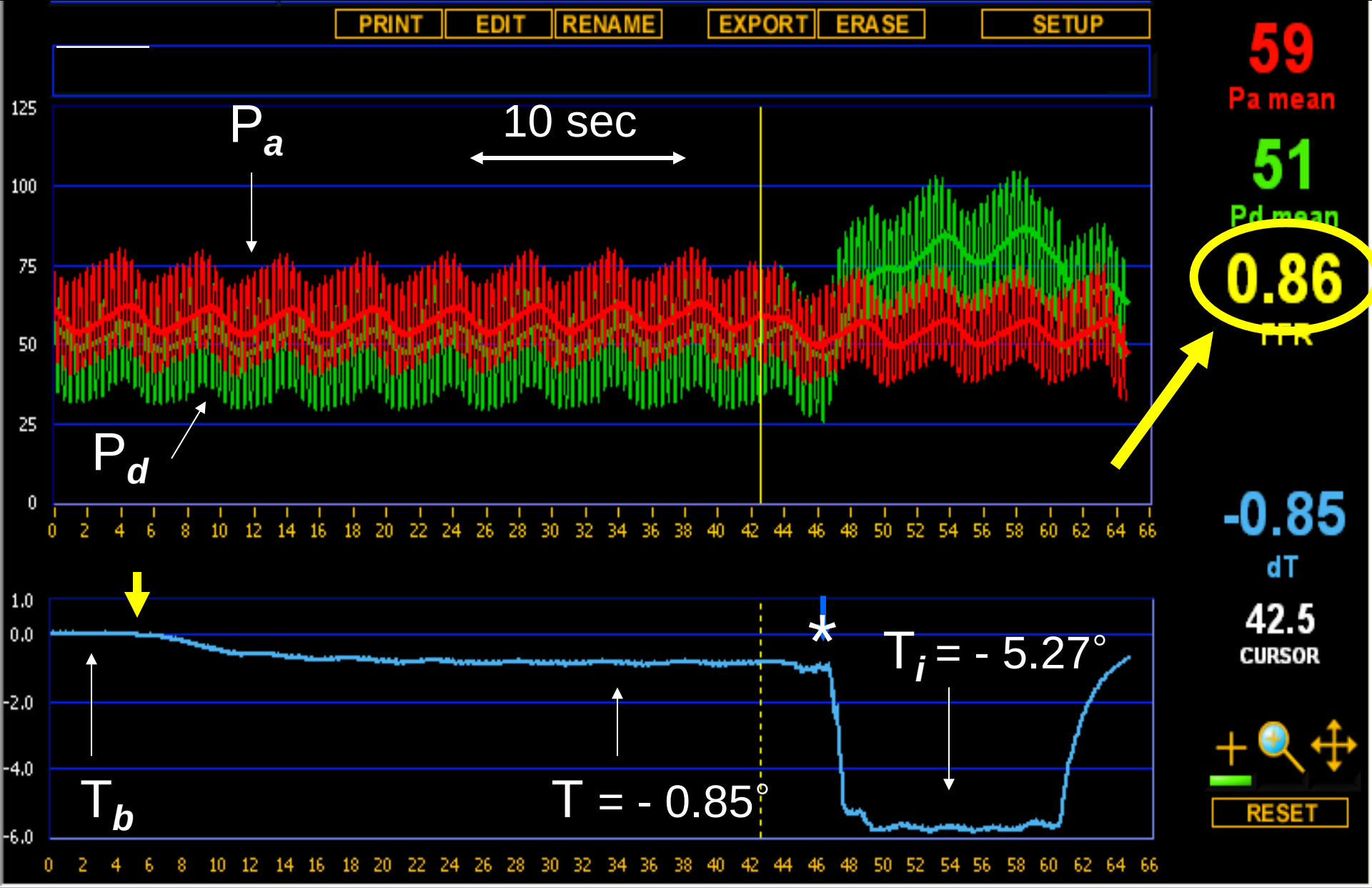


Q***b*** = 134 ml/min ⟶ <u>normal</u> max flow = 100/86 x 134 = 156 ml/min

	before PTCA	at occlusion	after PTCA
FFRmyo	0.50	0.18	0.97
FFRcor	0.39	-	0.96
Qc/Q^N	0.11	0.18	0.01

note: the values in this matrix are inependant of pressure or other hemodynamic variables. Such a matrix completely describes the distribution of flow in that part of the coronary circulation related to the respective artery.

The concept of FFR enables calculation of the separate contrubution of coronary and collateral flow to myocardial blood flow

In the present case:

Q_{myo} "normal" (i.e. without stenosis) = 156 ml/min

Q_{myo} = 146 ml/min $\quad R_{micro} = (P_d) / Q_{myo}$

Q_{cor} = 134 ml/min $\quad R_{cor} = (P_a - P_d) / Q_{cor}$

Q_{coll} = 12 ml/min $\quad R_{collat} = (P_{w\,-} - P_d) / Q_{coll}$

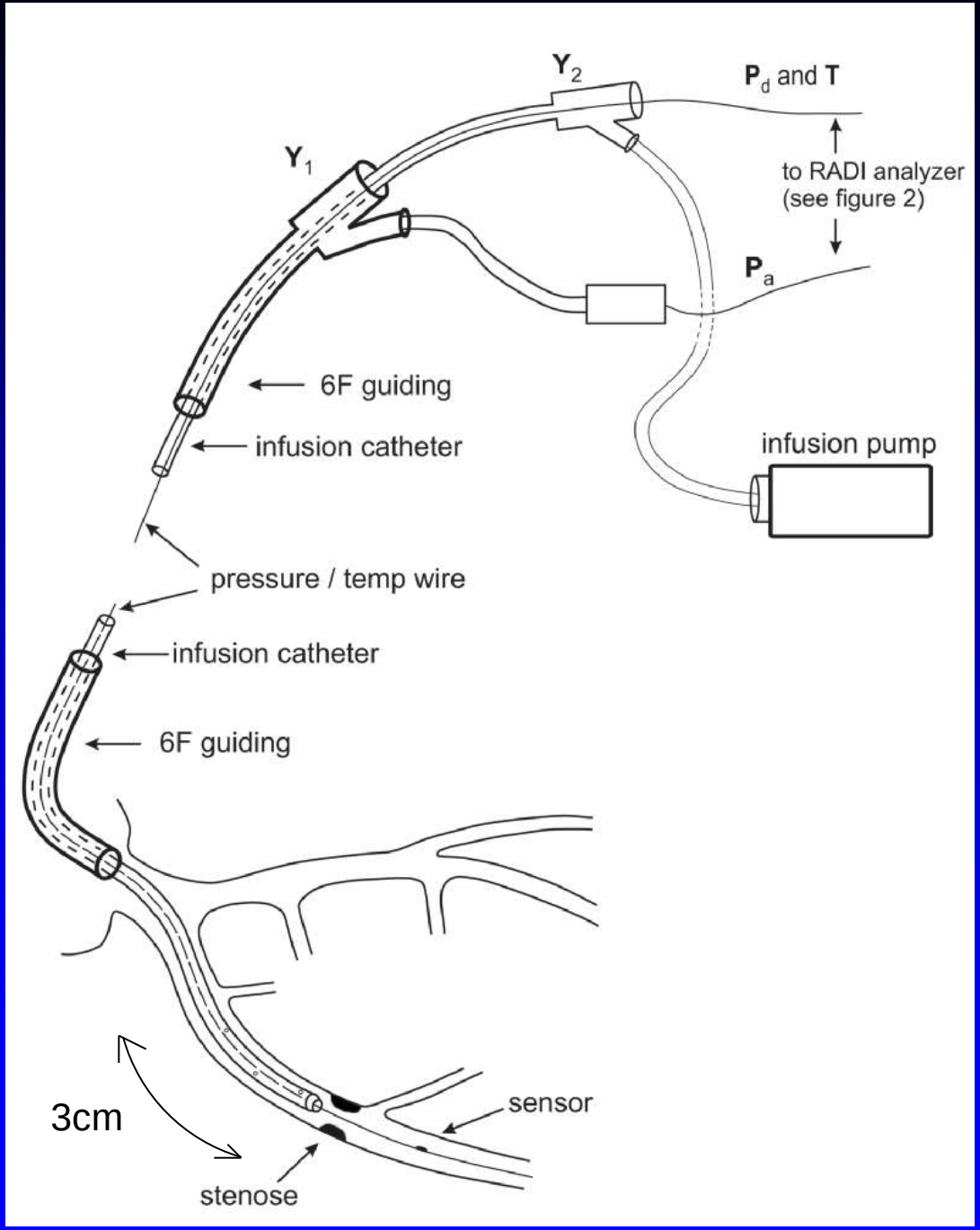
So, you calculate both the actual coronary,myocardial And collateral blood flow, ***AND*** the normal values of blood flow *(in ml/min)…*

…and because pressure is measured simultaneously, you also calculate ***absolute microvasular resistance*** *In dyn/sec/cm^{-5} (as well as its normal value)*

Instrumentation up to recently:

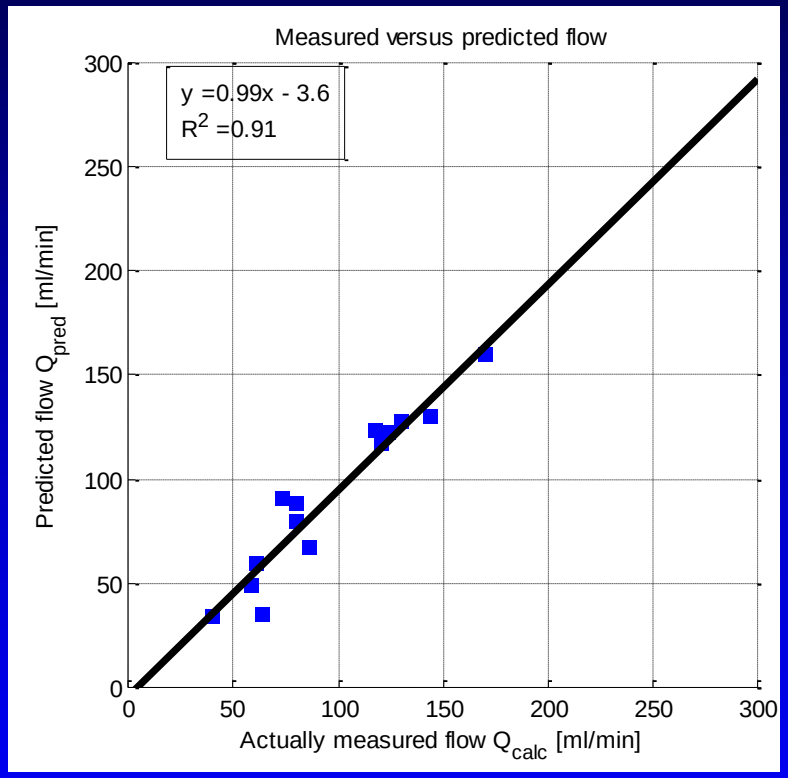
- OTW infusion catheter for infusion of saline
- 2 Y-connectors
- sustained iv infusion of adenosine for maximum hyperemia

(20-30 minutes and some specific skill of operator)



Validation in humans: 36 selected patients

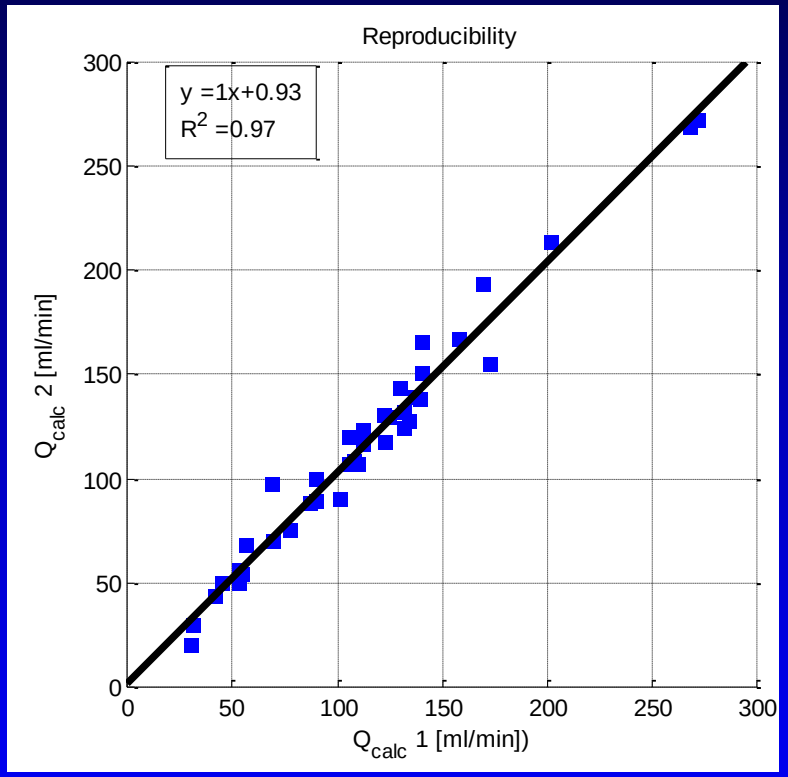
predicted flow



measured flow

N = 14

Measurement # 2



Measurement # 1

N = 22

Aarnoudse et al, JACC 2007; 50: 2294-2304
Otterspoor et al, Cather Cardiov Interv 2015, on-line

A NEW AVENUE TO THE CORONARY MICROCIRCULATION

→ *recently,* ***2 major breakthroughs*** *have simplified the technique considerably:*

- *a new* ***monorail infusion catheter*** ***and***
- ***saline induced maximum hyperemia***

What do you need?

1. Thermistor-wire and adequate software
   → *regular St Jude Medical Pressure wire*

2. Adequate infusion catheter for complete mixing → *Hexacath monorail catheter*

3. Sustained maximum hyperemia
   (= minimal microvascular resistance)
   → *saline infusion itself !*

Cardiovascular Center Aalst

Absolute Flow Measurements by Thermodilution

First Data with a Novel Catheter

(HexaFlow ®)

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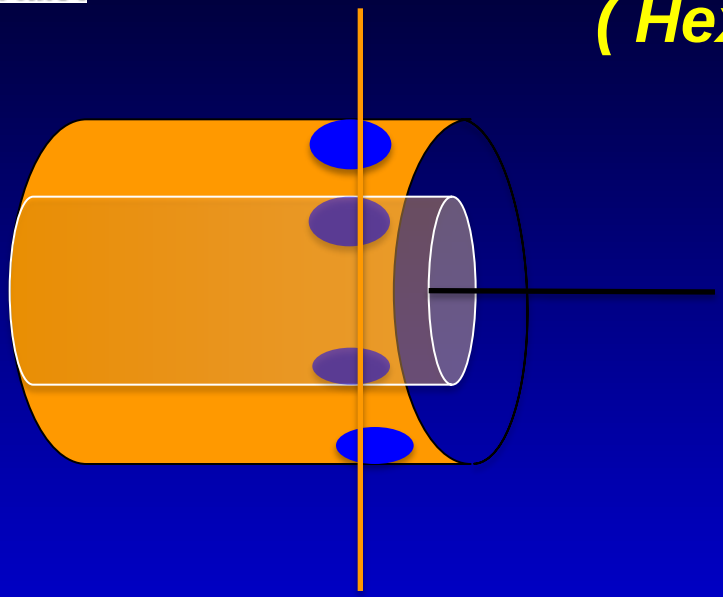
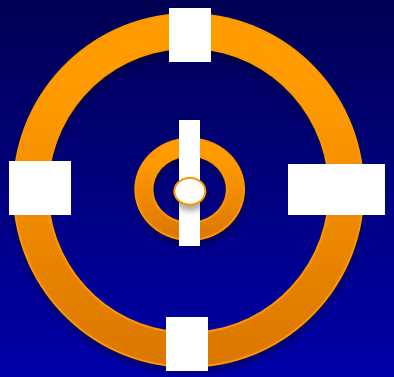
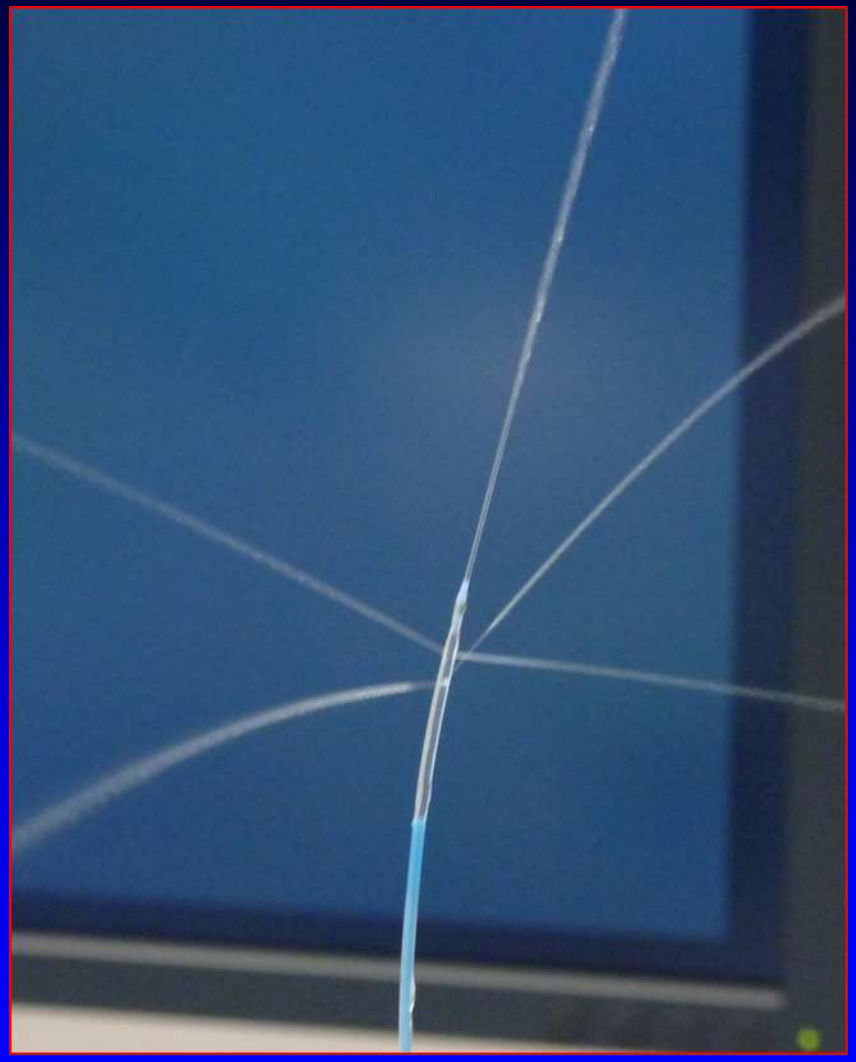




- Monorail infusion catheter with double lumen (Hexacath, Paris)
- Inner lumen to measure the infusion temperature
- Outer lumen to infuse saline via side holes

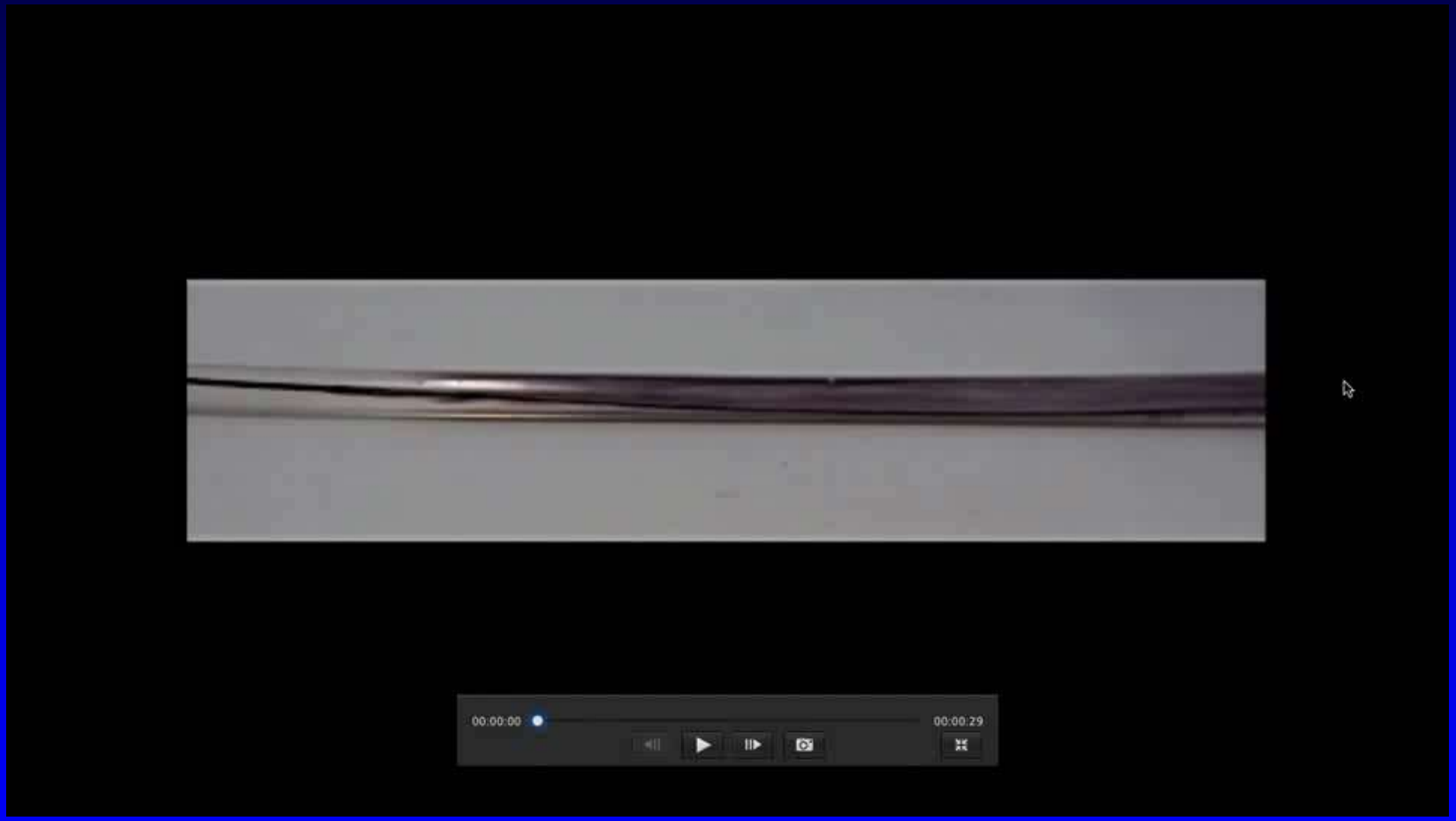
Infusion Catheter For Thermodilution (HexaFlow ®)

(complete mixing of blood and saline)

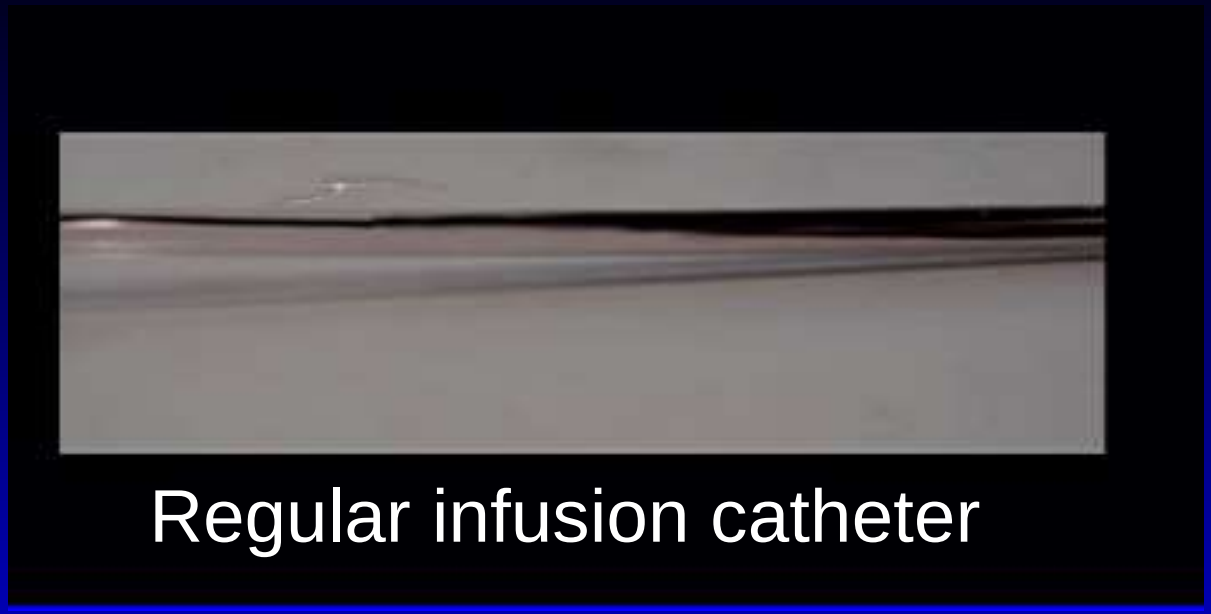


without guidewire

with guidewire



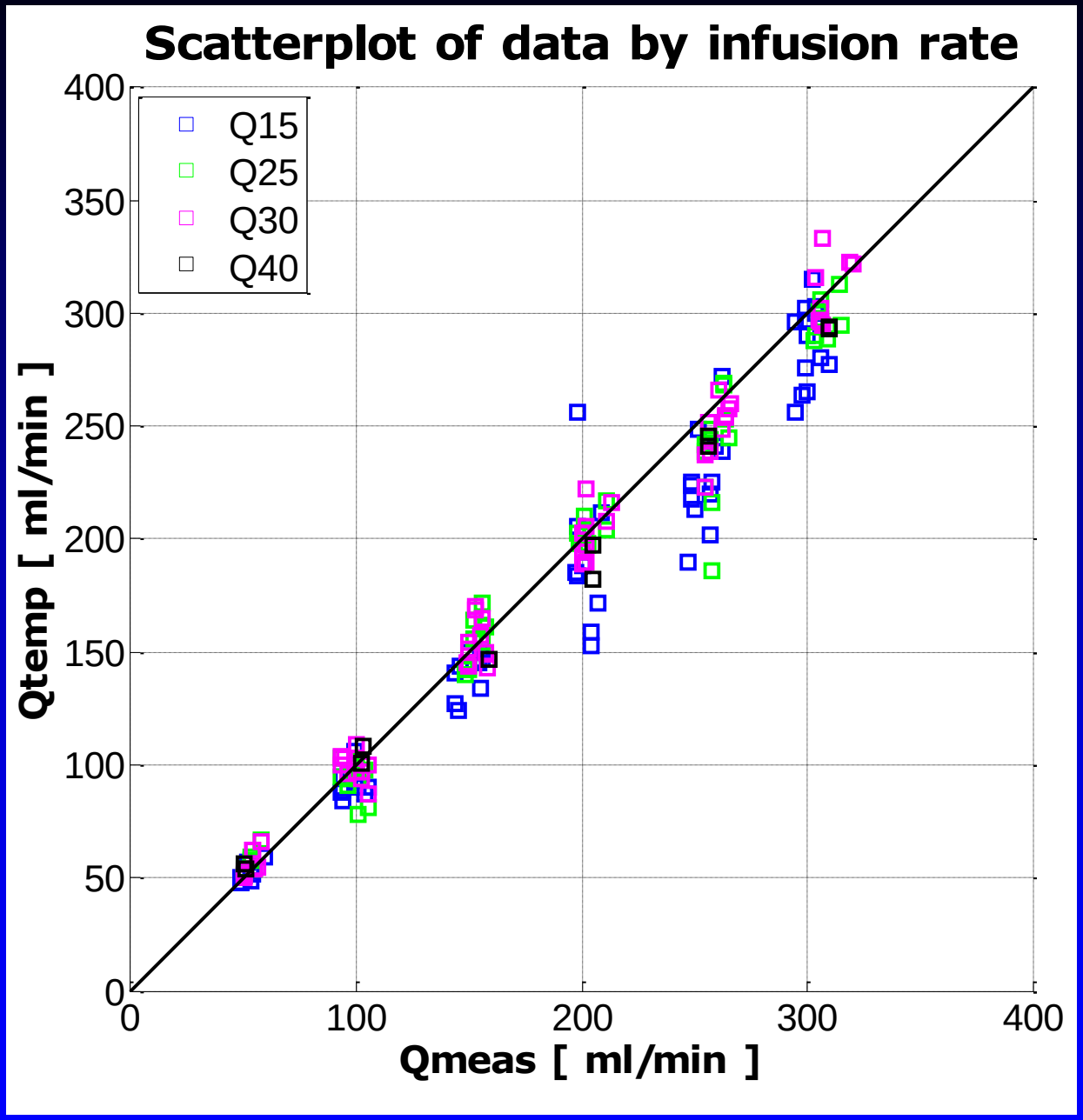
Sideholes are needed to obtain complete mixing of the indicator



Regular infusion catheter

Special monorail infusioncatheter (hexaflow®)

New monorail Infusion catheter (N=239)



measured flow versus calculated flow

Percentual difference between true flow and calculated flow

Infusion rate 15 ml/min: -6.4 ± 9.0 %

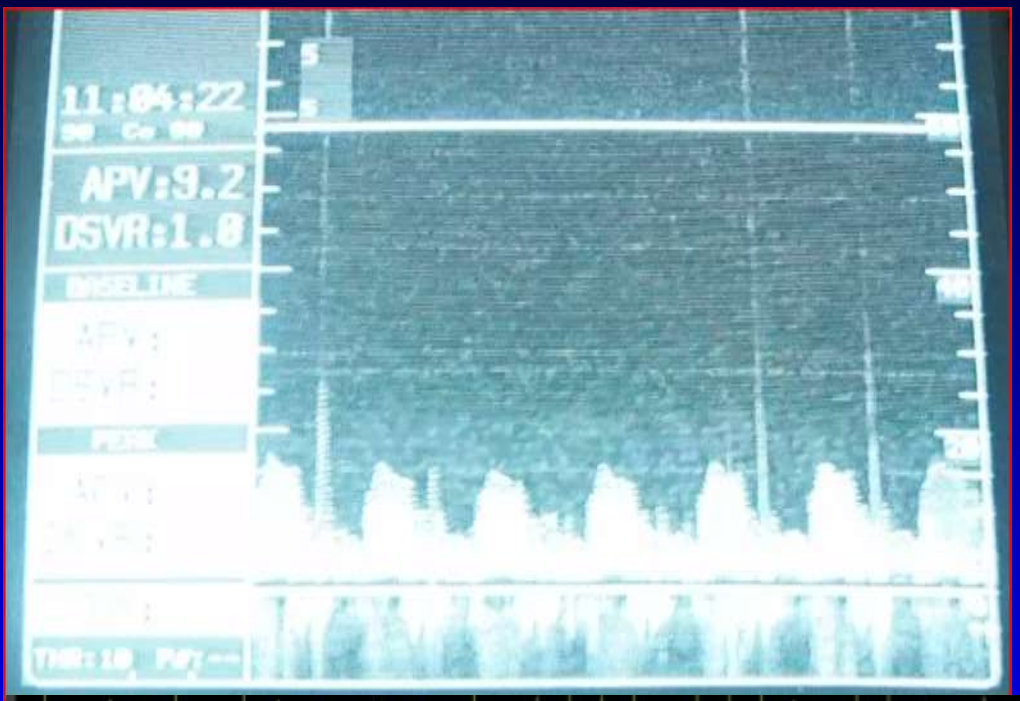
Infusion rate 30 ml/min: -0.1 ± 6.6 %

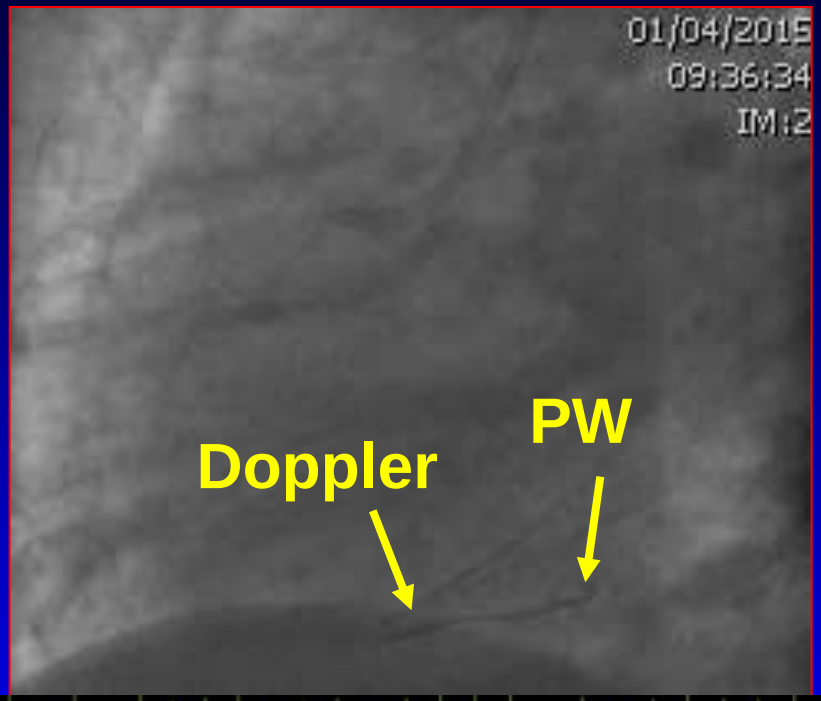
(most common infusion rate in humans)

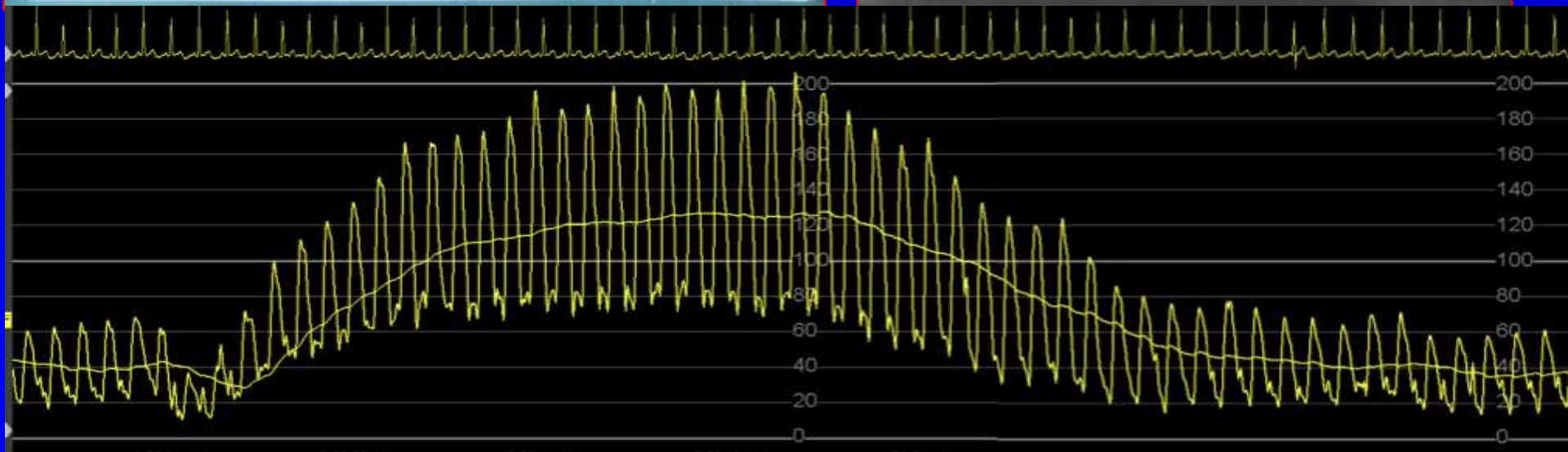
coronary saline infusion itself induce maximum hyperemia !

(thereby avoiding the necessity for separate Infusion of adenosine)

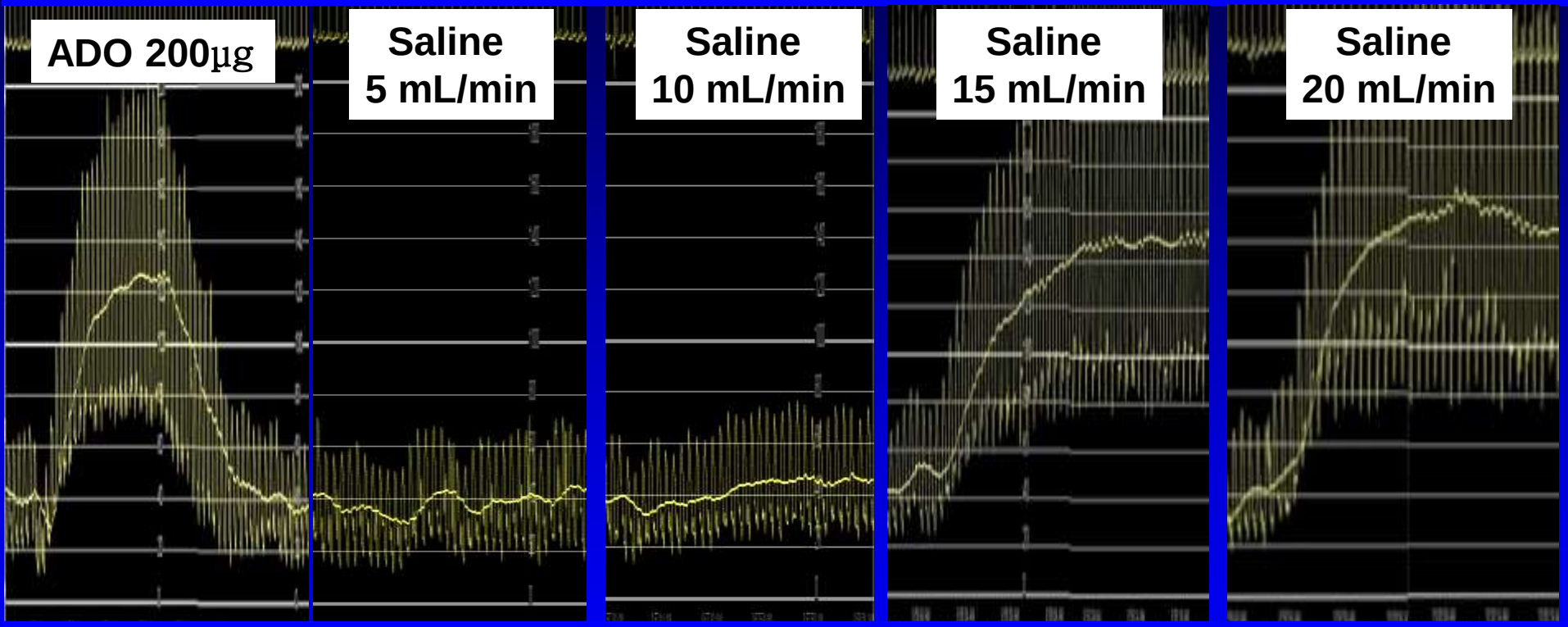
Flow Velocity Measurements Adenosine IC







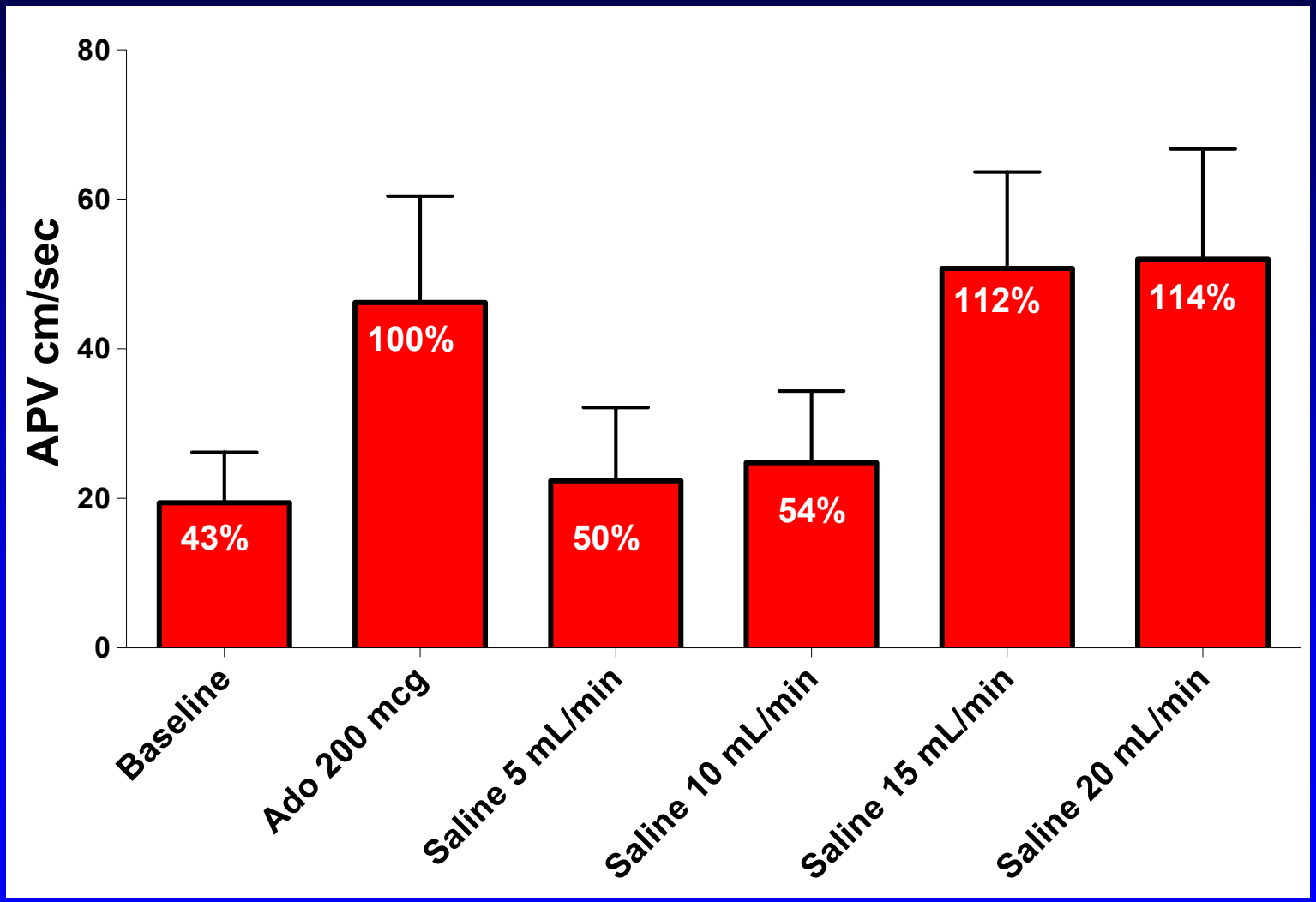
Effect on Saline Infusion on Coronary Flow



Continuous coronary infusion of Saline at a rate of 20 ml/min induces maximal hyperemia within 20 seconds

N = 18 Courtesy of Julian Adjedh and Bernard De Bruyne

Coronary saline infusion induces Maximal Hyperemia



N = 18 Courtesy of Julian Adjedh and Bernard De Bruyne

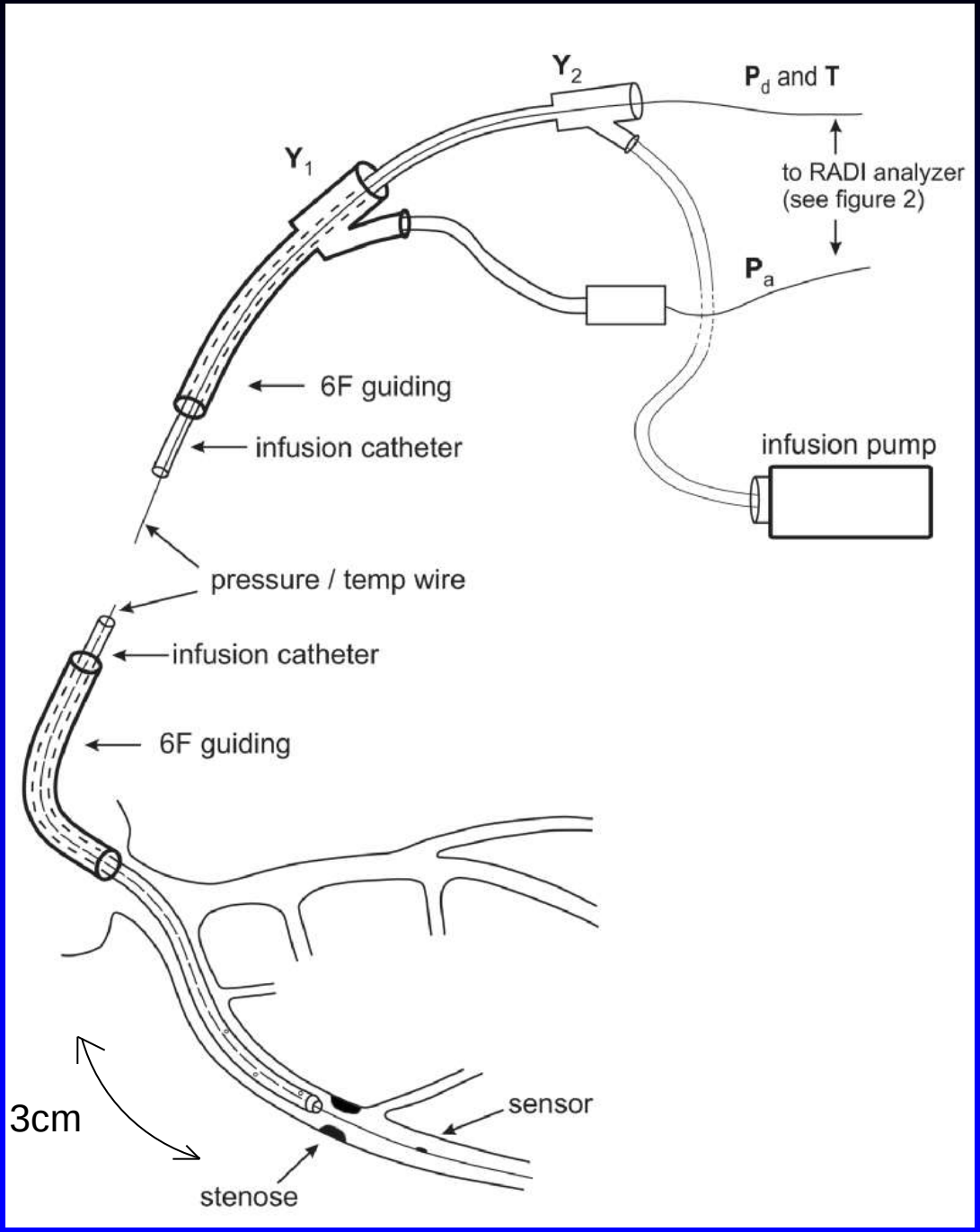
Instrumentation today:

- OTW infusion catheter for infusion of saline
- 2 Y-connectors

→ monorail infusion catheter *(FlowCath ®)*

- sustained iv infusion of adenosine for maximum hyperemia

→ Saline infusion itself is hyperemic

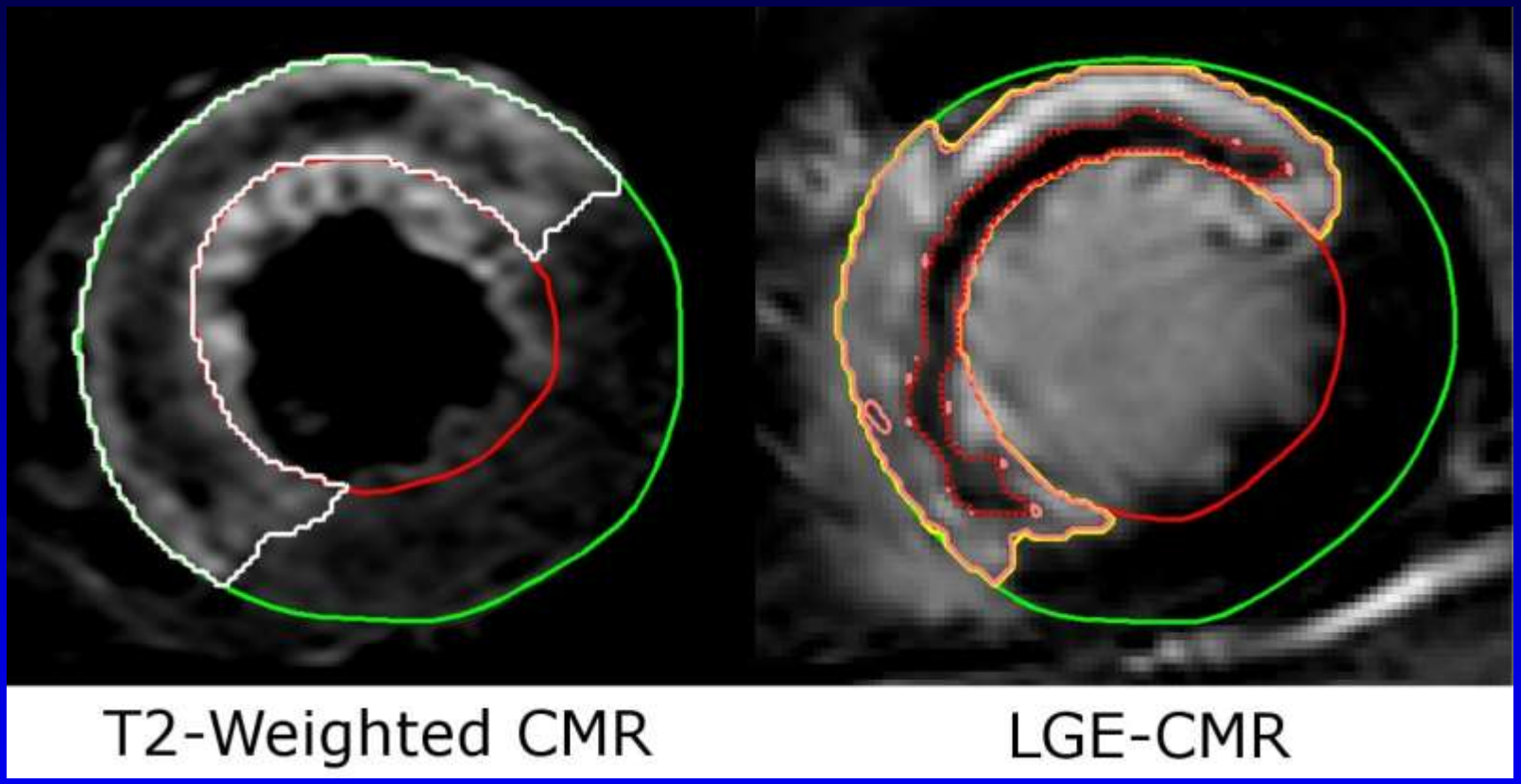


Example: Application in acute STEMI:

Measurement of microvascular resistance
Immediately after PPCI and after 5 days
(N = 20)

⟶ *evaluation of microcirculatory resistance*
In the first days after STEMI

Wijnbergen et al, in press



Area at risk and infarcted area by MRI

absolute flow in the infarct area (ml/min/g)

absolute resistance in the infarct Area ($dyn.s.cm^{-5}$)

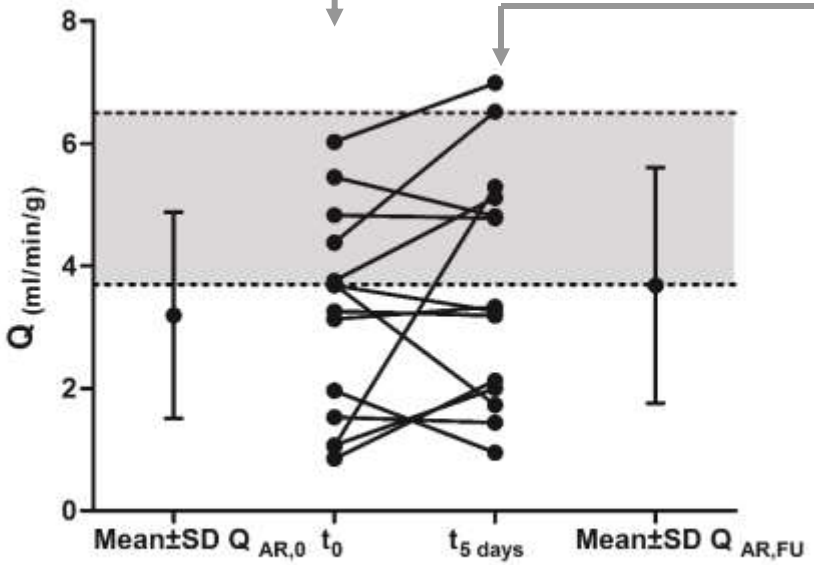


Figure 4a

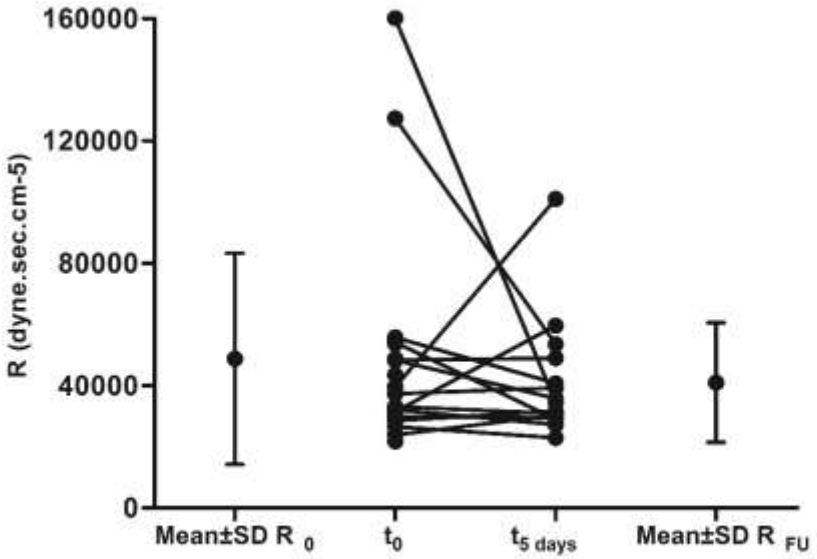


Figure 4b

hyperacute phase
day 5

Wijnbergen et al, in press

Absolute flow in ml/min/g: correlation with IMR

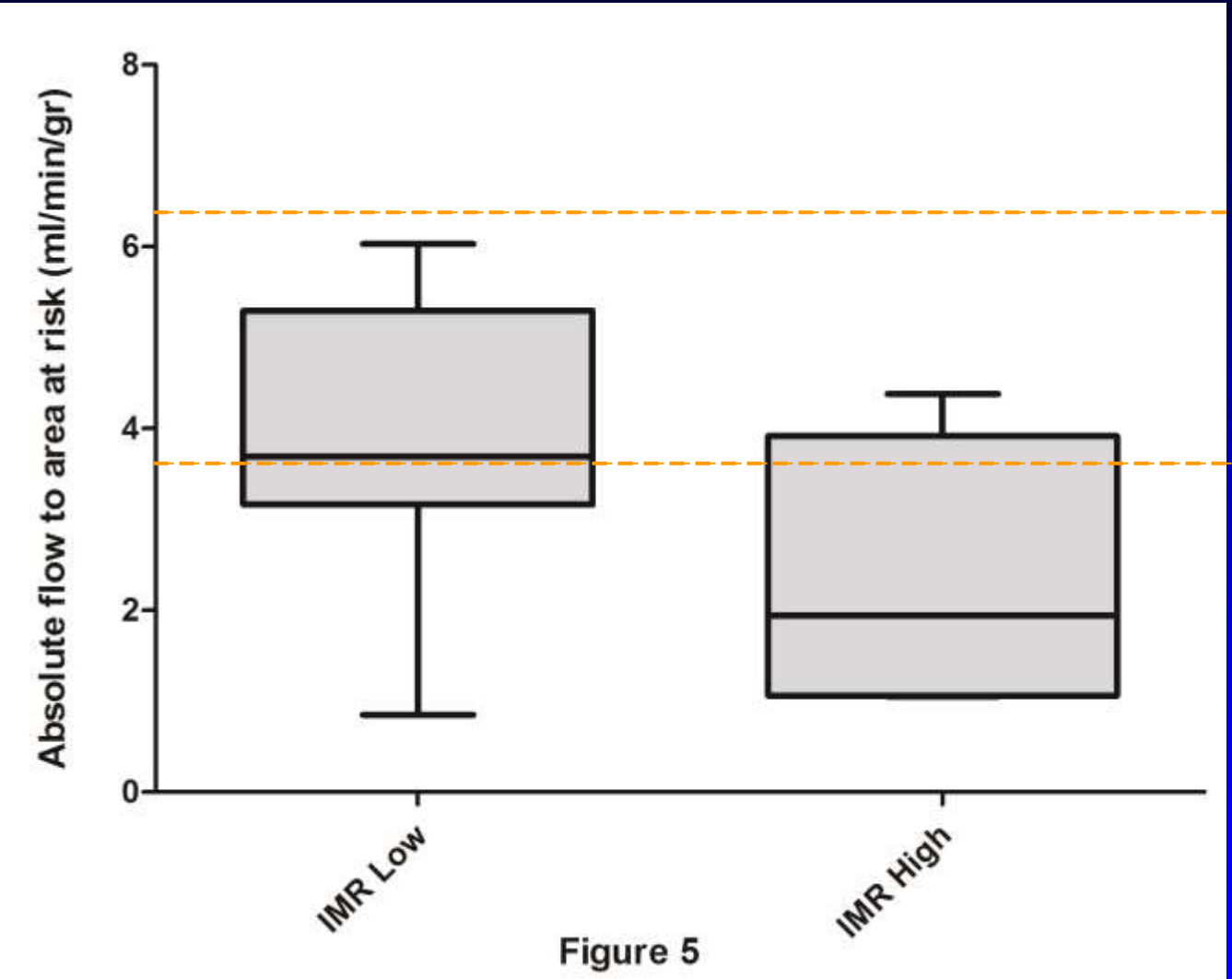


Figure 5

Wijnbergen et al, submitted

A NEW AVENUE TO THE CORONARY MICROCIRCULATION

continuous infusion of saline and thermodilution enables measurement of absolute coronary flow and microvascular resistance

- easy to perform with standard PCI equipment
- with the new monorail infusion catheter *(FlowCath ®)* it takes only 5 – 10 minutes
- the saline infusion itself guarantees maximum hyperemia; no additional stimulus necessary
- accurate and reproducible
- *operator-independent, you can continue the measurement for minutes*