

15.-17. DUBNA 2026 | TŘINEC

XXXV.

WORKSHOP ČESKÉ ASOCIACE
INTERVENČNÍ KARDIOLOGIE

Od makrocirkulace k mikrocirkulaci – komplexní koronární fyziologie

Tomáš Kovárník



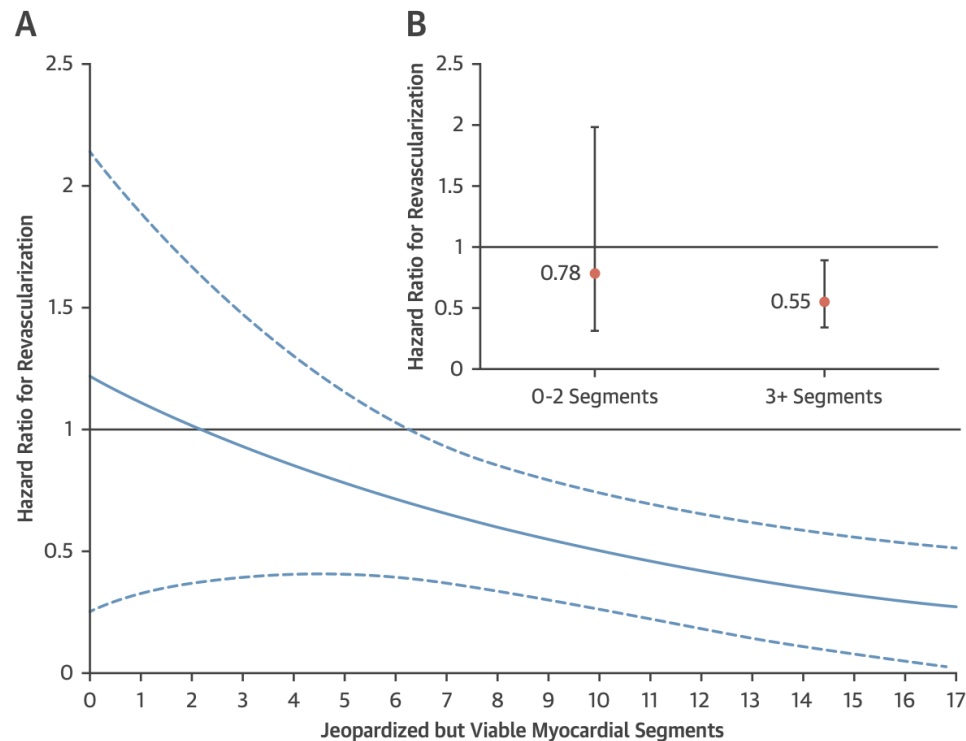
ORIGINAL RESEARCH

Patient-Specific Registration of Segmental Jeopardy and Viability

Novel Method to Guide Revascularization in Ischemic Cardiomyopathy

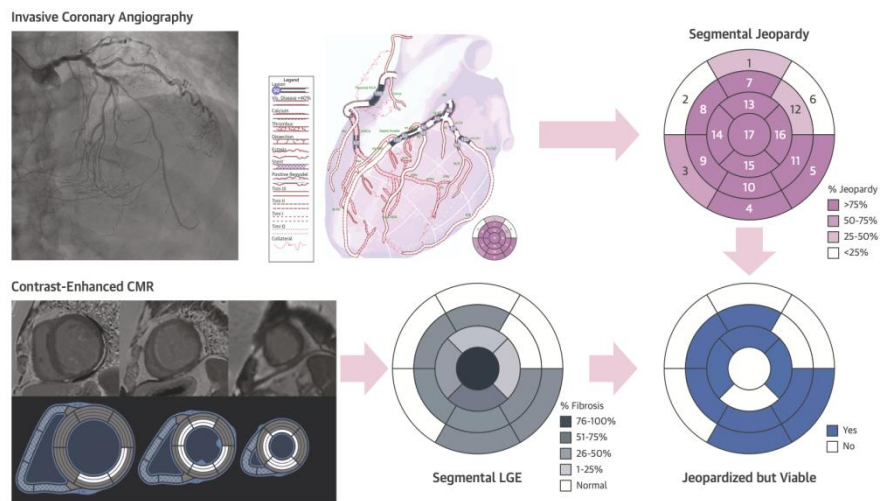
Jacob Abdaem, MD,^{a,b,*} Dina Labib, MD, PhD,^{a,b,c,*} Rhys Beaudry, PhD,^{a,b,c} Augustine Amakiri, PhD,^{a,b}

FIGURE 4 Relationship Between Jeopardized but Viable Myocardial Segments and Early Revascularization



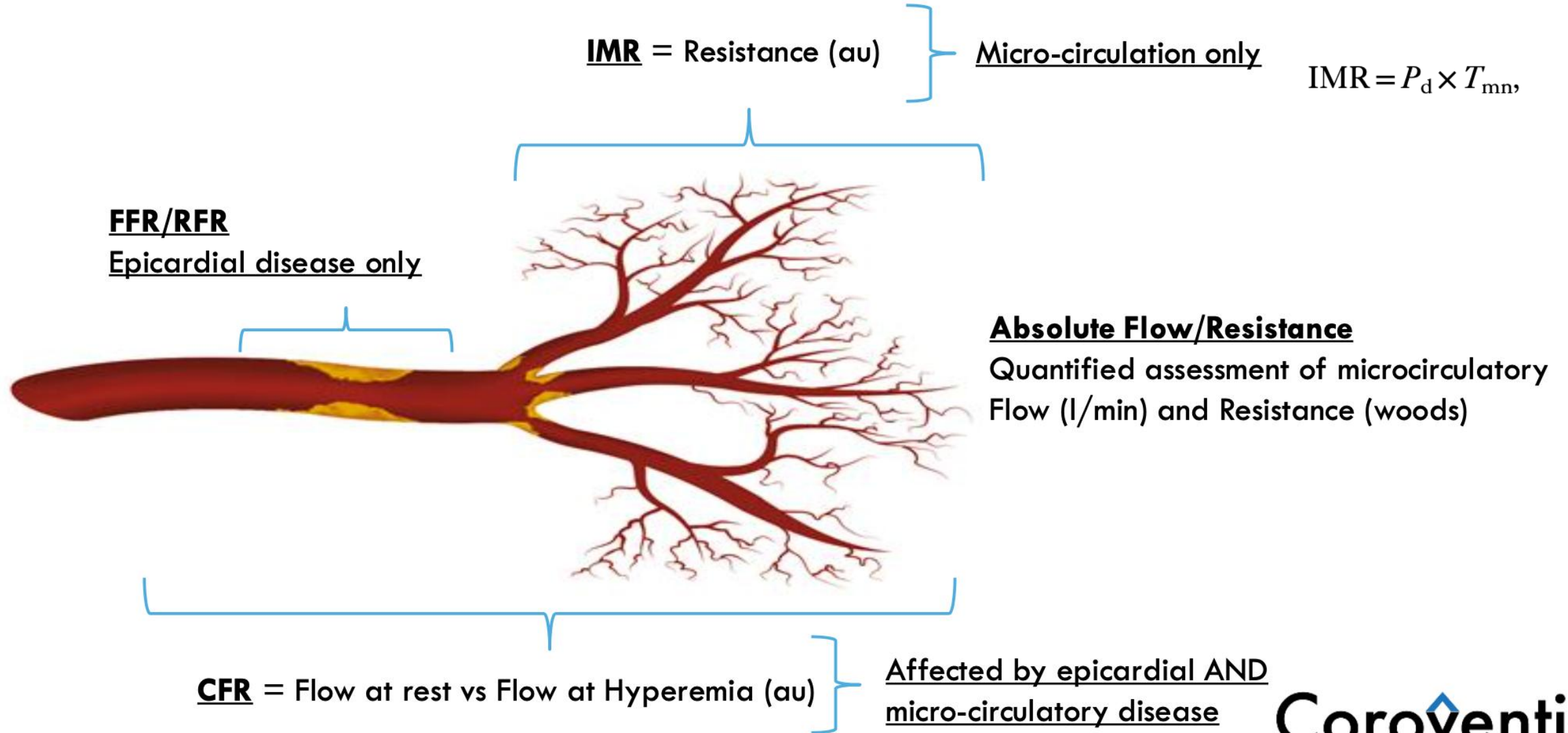
(A) HR for all-cause mortality with revascularization according to the number of jeopardized but viable myocardial segments. (B) Comparison of HRs for revascularization in patients with 0 to 2 vs 3+ jeopardized but viable myocardial segments.

FIGURE 1 Case Example

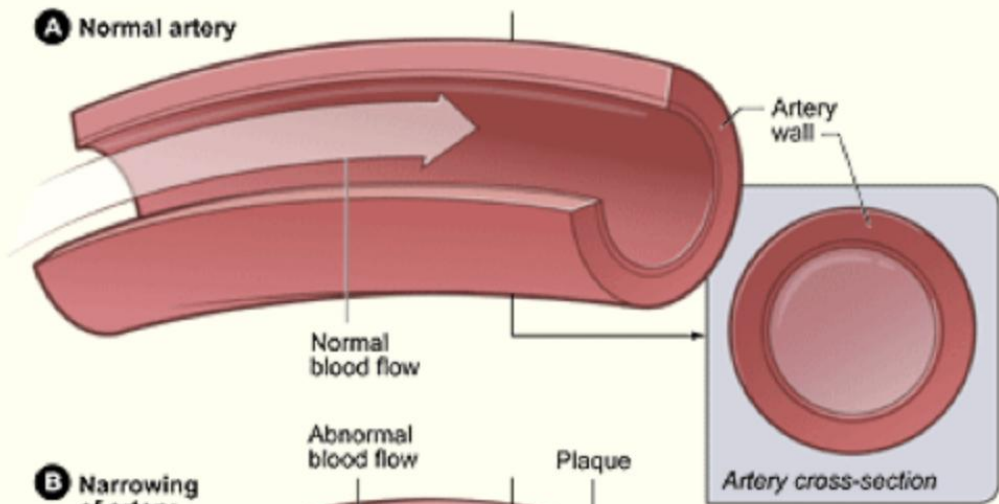


A 70-year-old woman with multivessel coronary artery disease and a left ventricular ejection fraction of 34%. (Top left) Invasive coronary angiography image shows

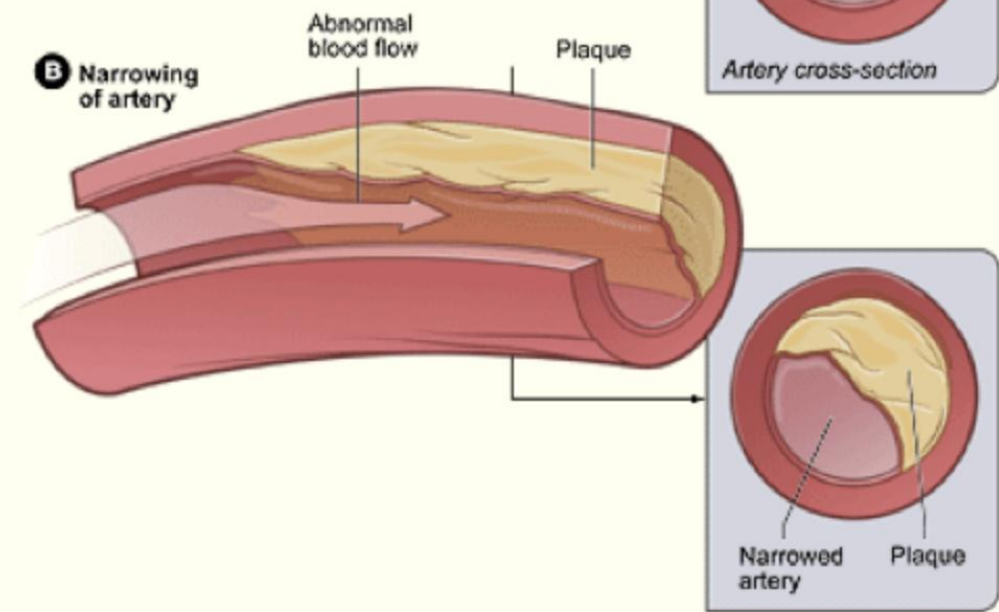
COMPLETE CARDIAC CHARACTERIZATION



A Normal artery



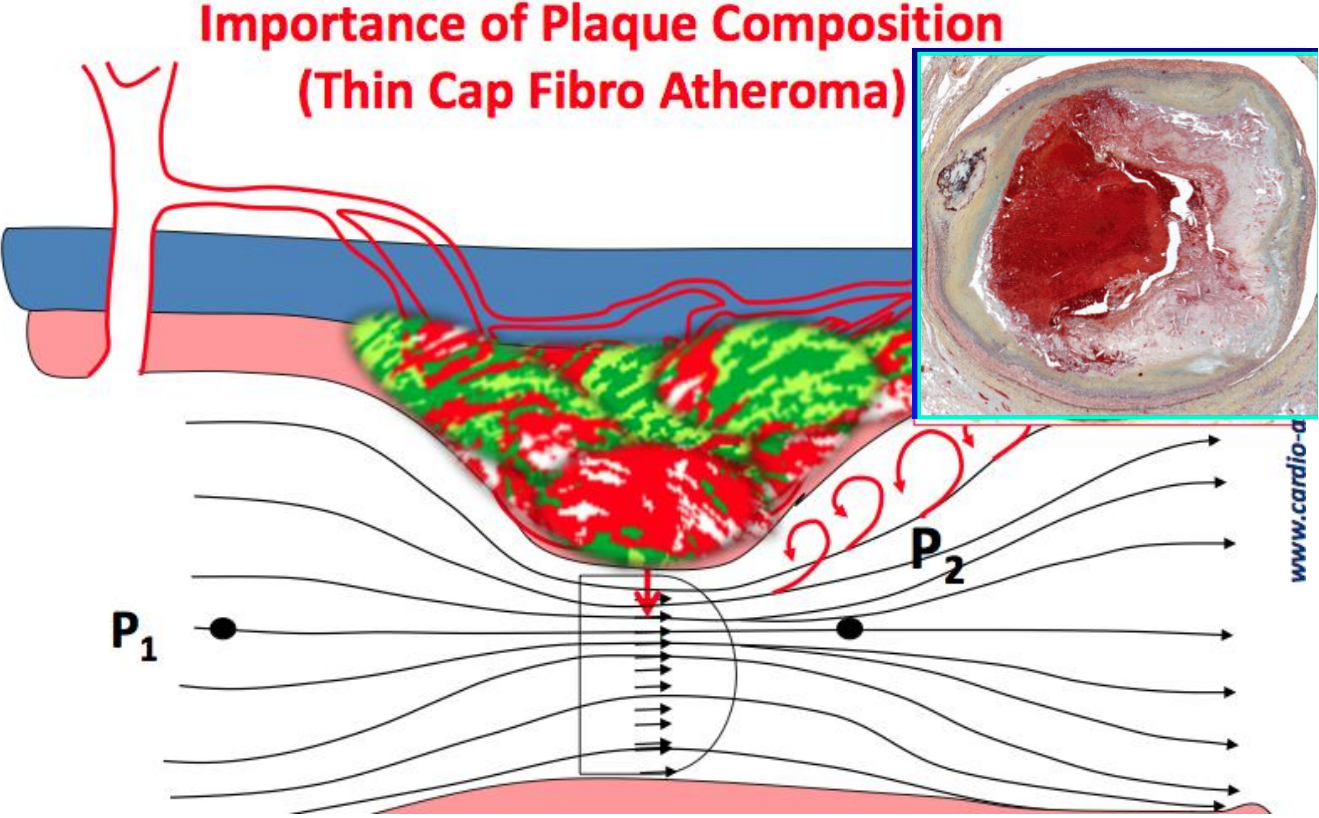
B Narrowing of artery



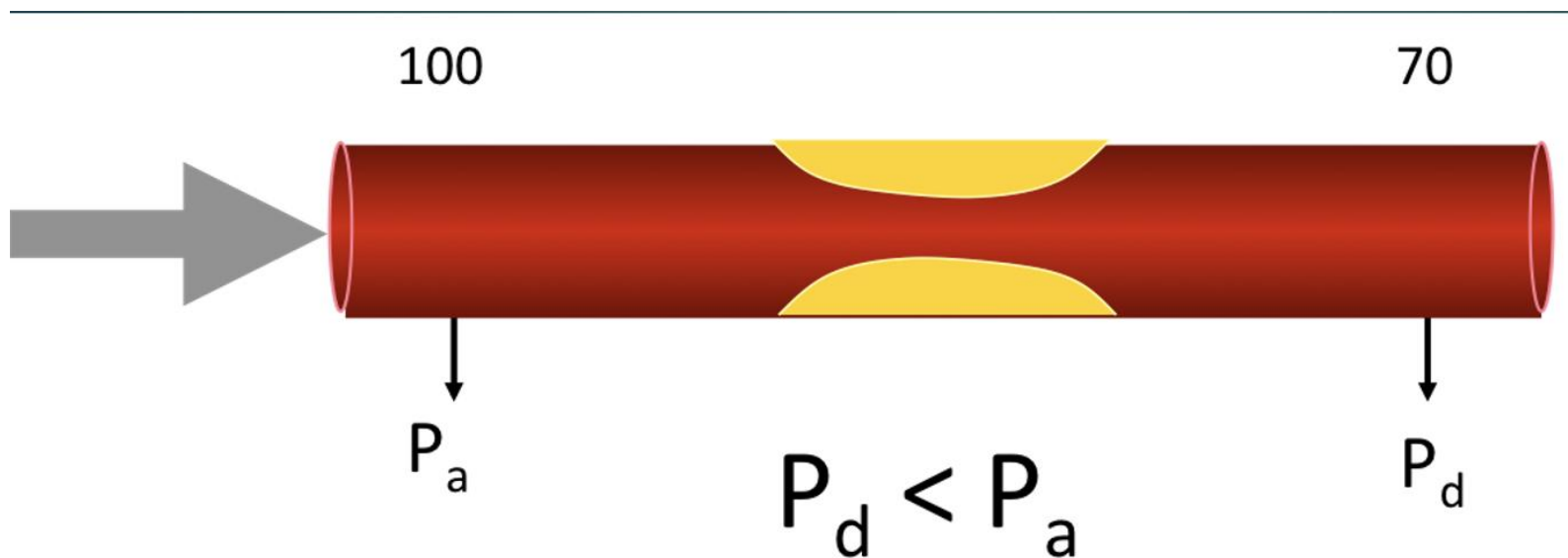
is NOT



Morphological consequences of pressure gradient



Frakční průtoková rezerva



$$FFR = P_d / P_a = 0.7$$

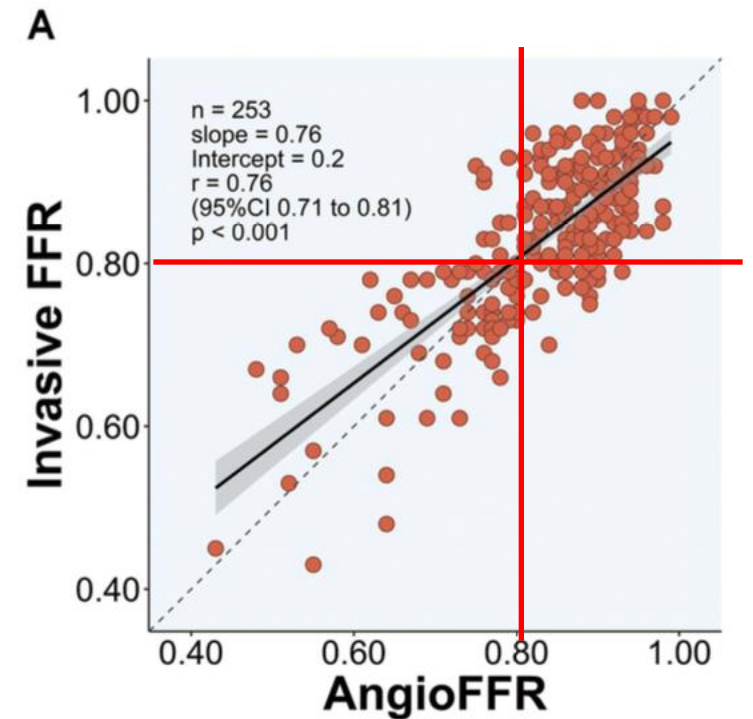
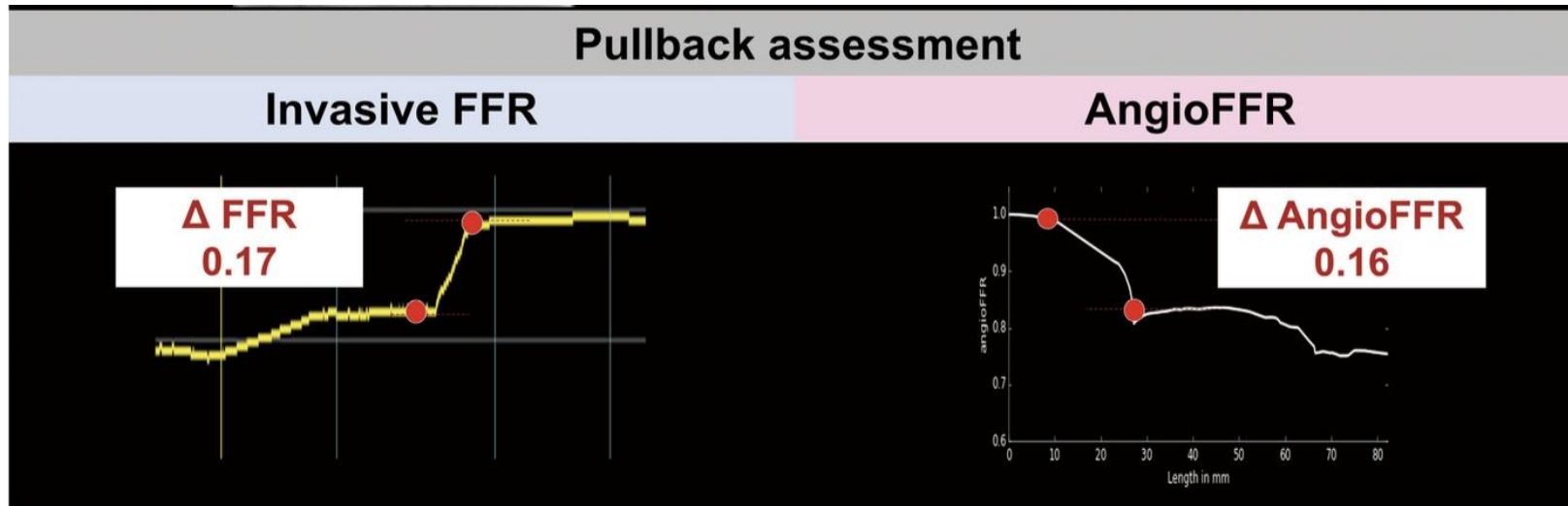
• FFR/iFR (significant ≤ 0.8 or ≤ 0.89 , respectively);^{49,308,310,311,313,321–323,332,373}

• QFR (significant ≤ 0.8).^{325,355,374,375}

I	A
I	B

Diagnostic Accuracy of Artificial Intelligence-Based Angiography-Derived Fractional Flow Reserve Using Pressure Wire-Based Fractional Flow Reserve as a Reference

Hiroyuki Omori, MD; Yoshiaki Kawase, MD; Takuya Mizukami, MD, PhD;



Koncept frakční průtokové rezervy

- 1) Poměr maximální průtoku ve stenotické tepně a normální průtoku při teoretické absenci stenózy:

$$FFR = \frac{Q_s}{Q_n}$$

- 2) Průtok je rovinu podílu tlakového rozdílu a myokardiální rezistence:

$$Q = \frac{\Delta P}{R}$$

- 3) Při maximální hyperemii je rezistence minimální:

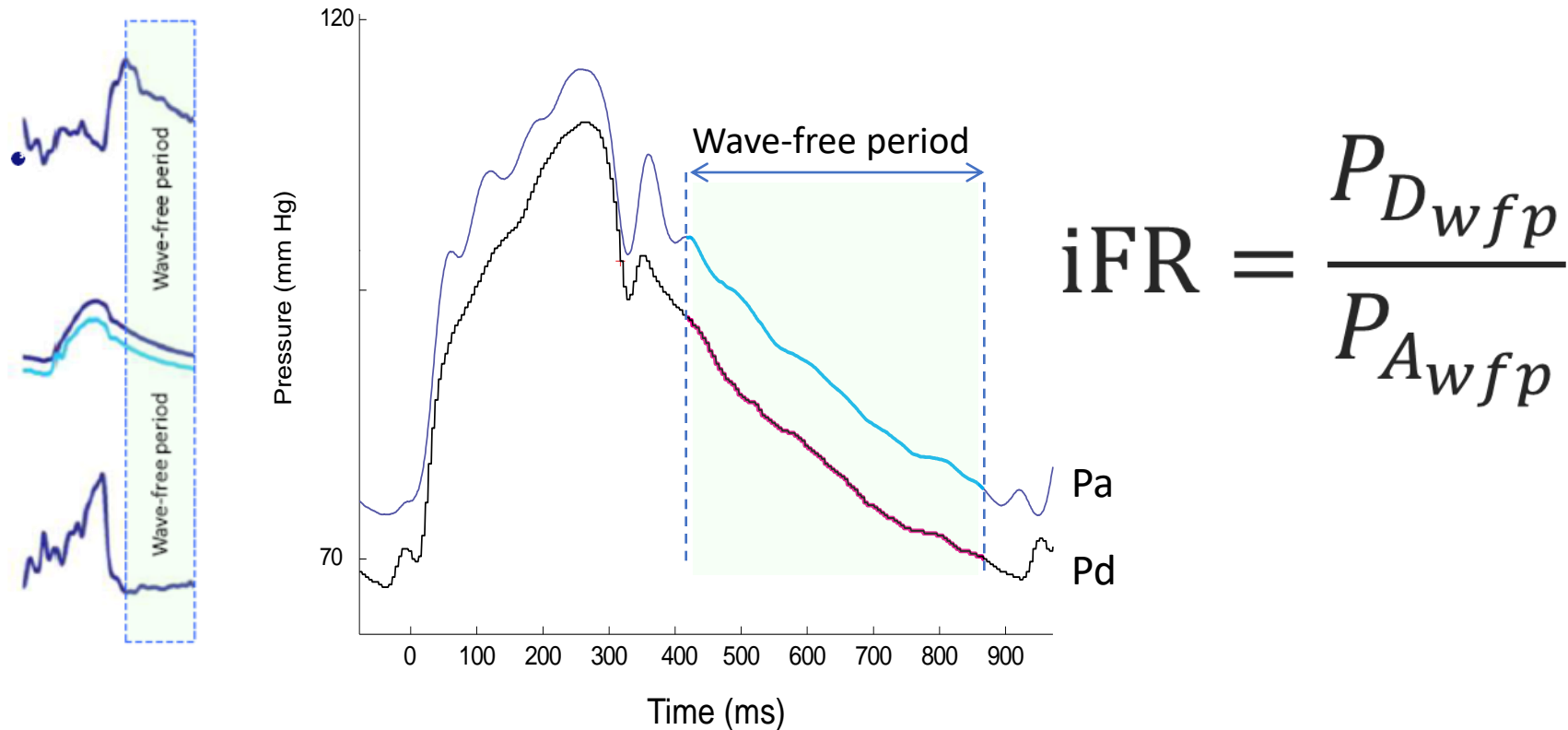
$$FFR = \frac{P_d - P_v}{P_a - P_v}$$

- 4) Vliv centrálního žilního tlaku je ve většině případů zanedbatelný:

$$FFR = \frac{P_d}{P_a}$$

$$\Delta P = \underbrace{f_1(1/A_s^2, l, \dot{Q})}_{\text{VISCOUS}} + \underbrace{f_2(1/A_s^2, 1/A_n^2, \dot{Q}^2)}_{\text{SEPARATION}}$$

Definice iFR



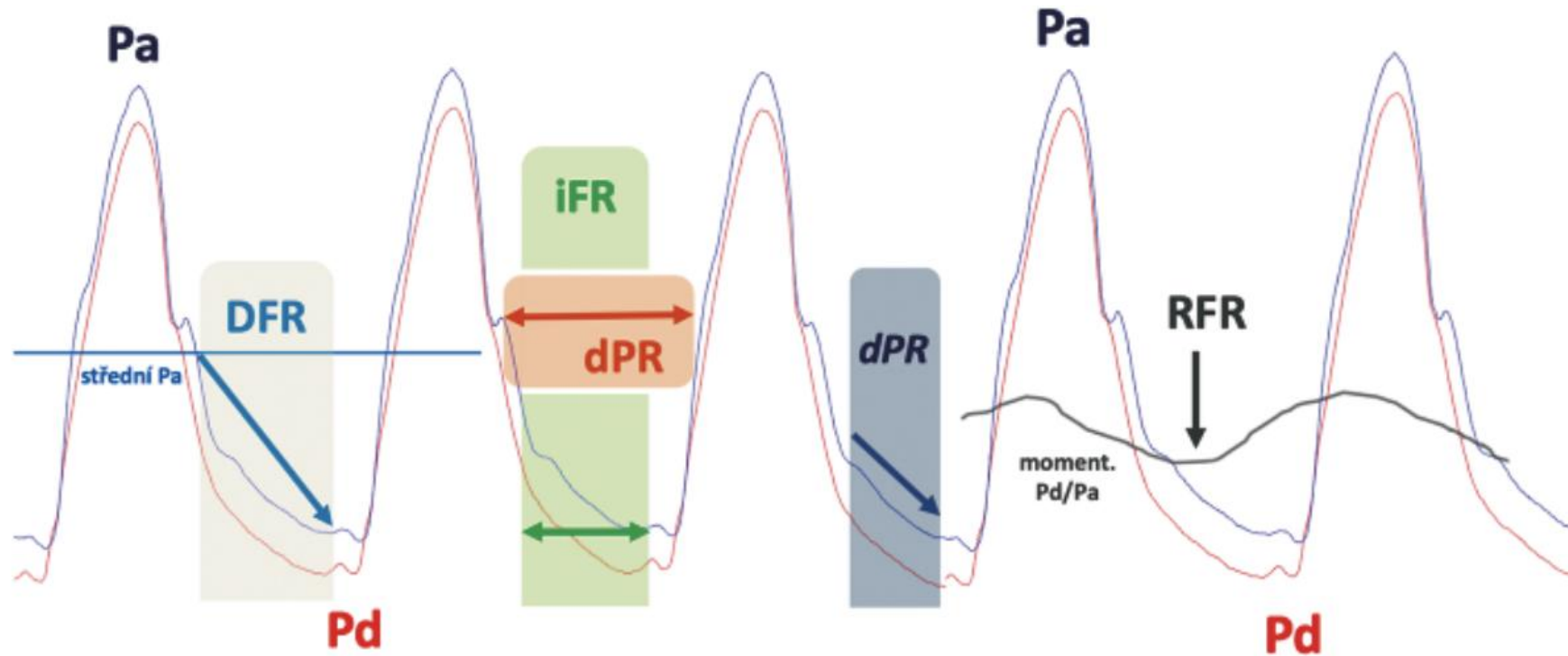
iFR is a pressure gradient measured during the phase of minimal vessel resistance, so called wave free period

Pd – distal pressure

Pa – proximal pressure

Wfp – wave free period

Non-hyperemic indices

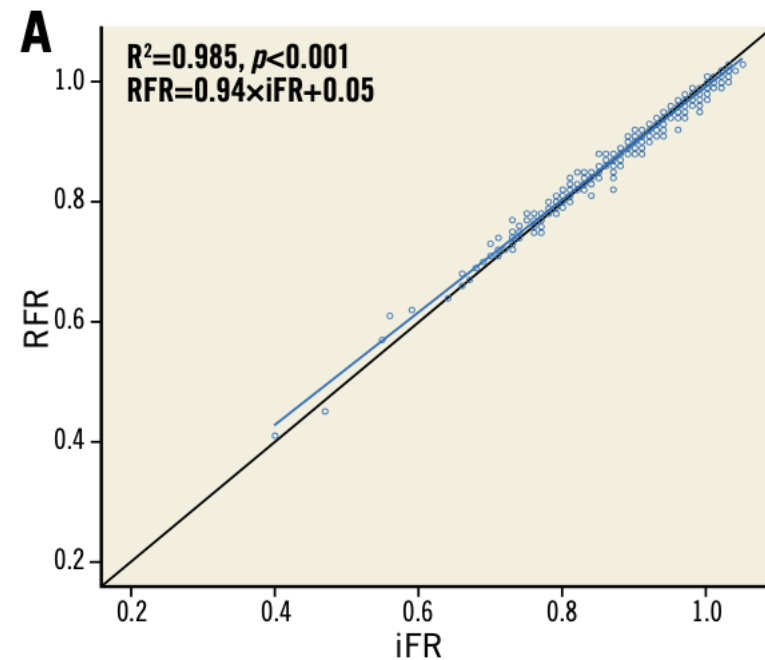
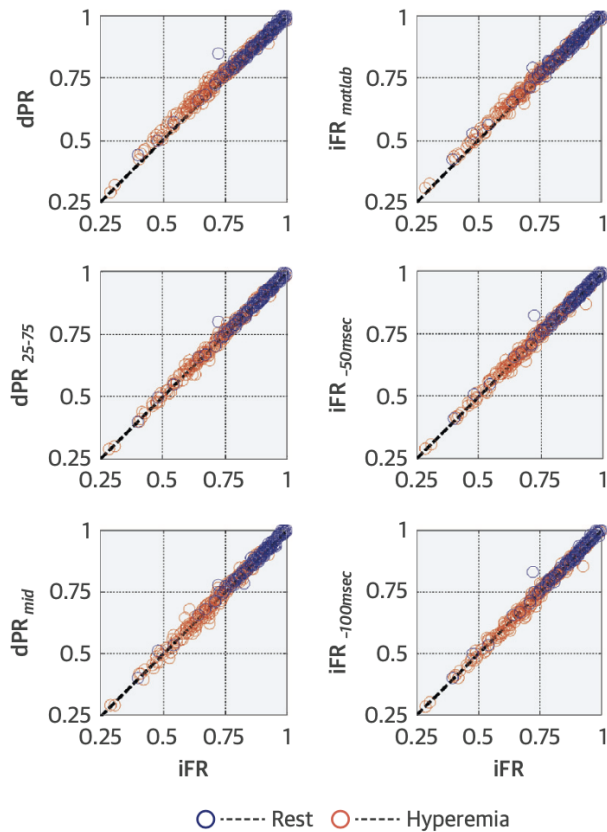
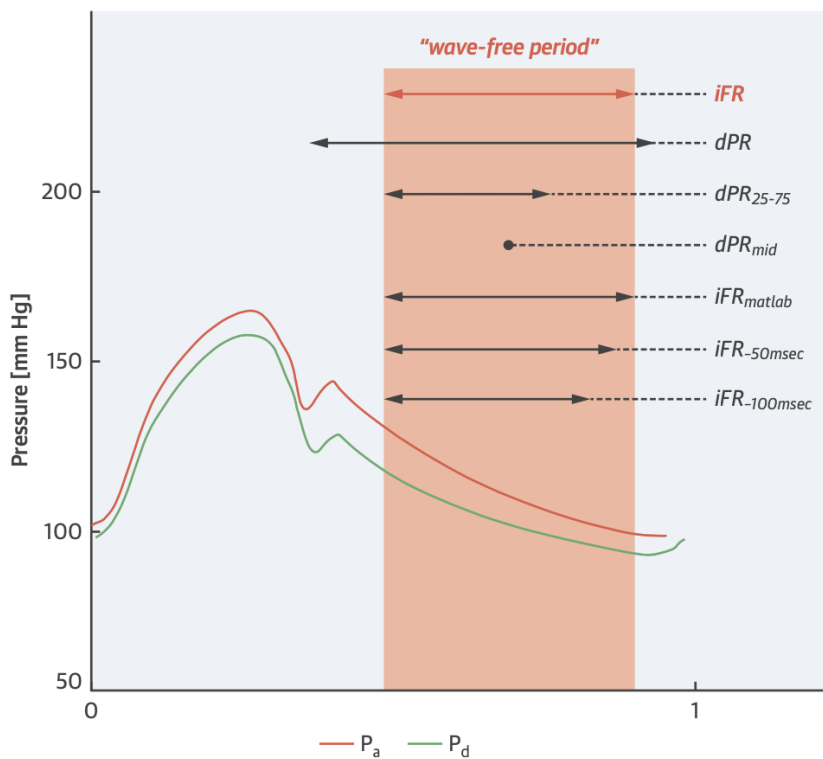




Comparison of Different Diastolic Resting Indexes to iFR

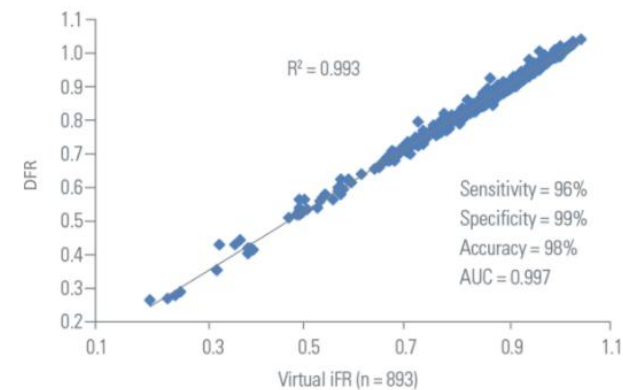
Are They All Equal?

Marcel van't Veer, MSc, PhD,^{a,b} Nico H.J. Pijls, MD, PhD,^{a,b} Barry Hennigan, MB BCH BAO, BMEDSCI,^{c,d}



EuroIntervention 2018;14:806-814

VERIFY 2 + CONTRAST Pooled Analysis: DFR Showed Equivalency to iFR



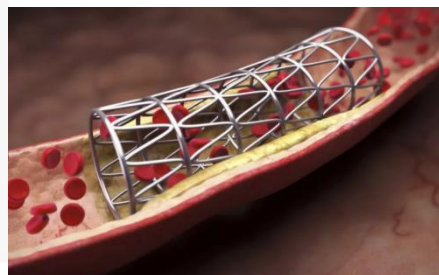
FFR a klidové indexy



FFR negativní



FFR pozitivní



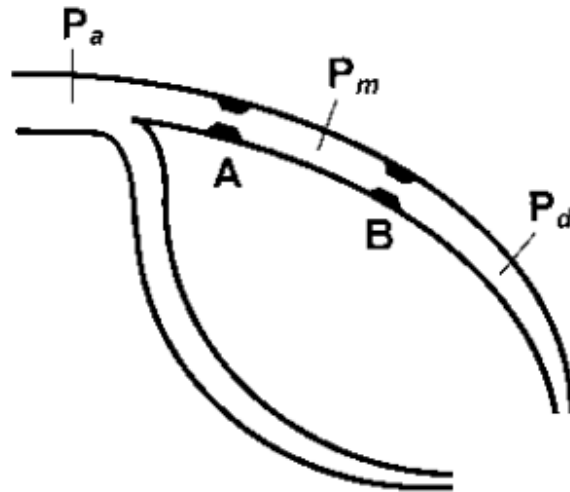
FFR / RI negativní

FFR pozitivní / RI negativní
FFR negativní / RI pozitivní

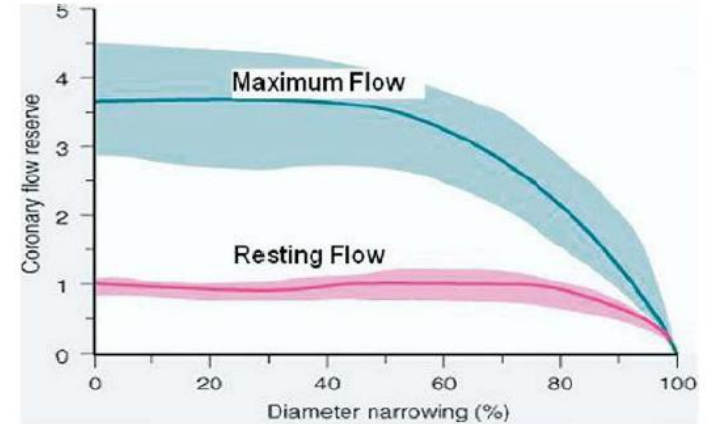
SO WHAT?

FFR / RI pozitivní

Hodnocení seriových stenóz a difúzního postižení



$$\begin{aligned} \text{FFR}(A+B) &= P_d / P_a \\ \text{FFR}(A)_{app} &= P_m / P_a \\ \text{FFR}(B)_{app} &= P_d / P_m \end{aligned}$$

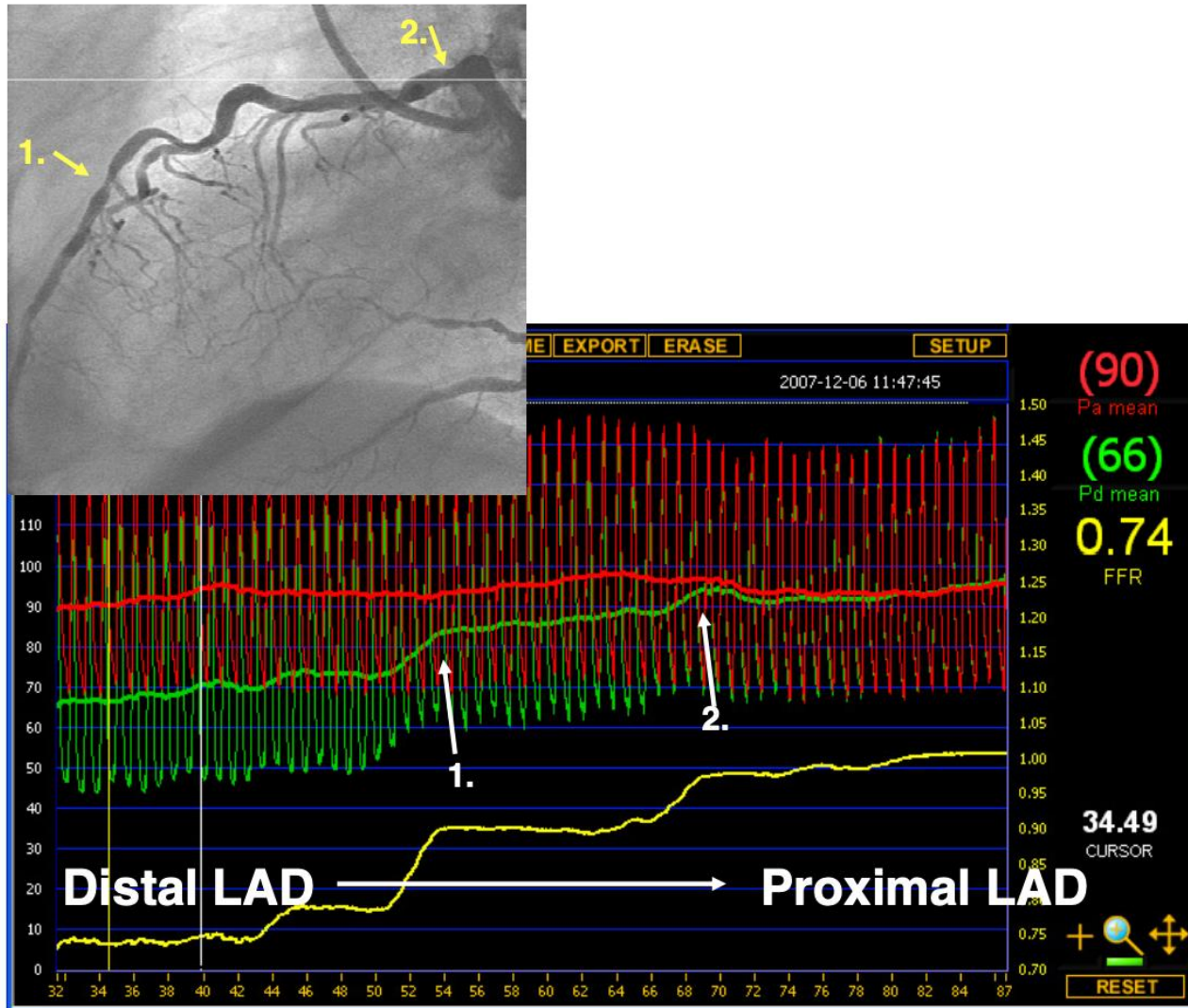


Gould et al., Am J Cardiol 1974;33:87-94 (from Braunwald's Heart Disease 2005)

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

$$\text{FFR}(B)_{pred} = 1 - \frac{(P_m - P_d) \cdot (P_a - P_w)}{P_a \times (P_m - P_w)}$$

FFR pullback



Measurement of Hyperemic Pullback Pressure Gradients to Characterize Patterns of Coronary Atherosclerosis



Carlos Collet, MD,^{a,*} Jeroen Sonck, MD,^{a,b,*} Bert Vandeloo, MD,^c Takuya Mizukami, MD, PhD,^{a,d}

PPG index =

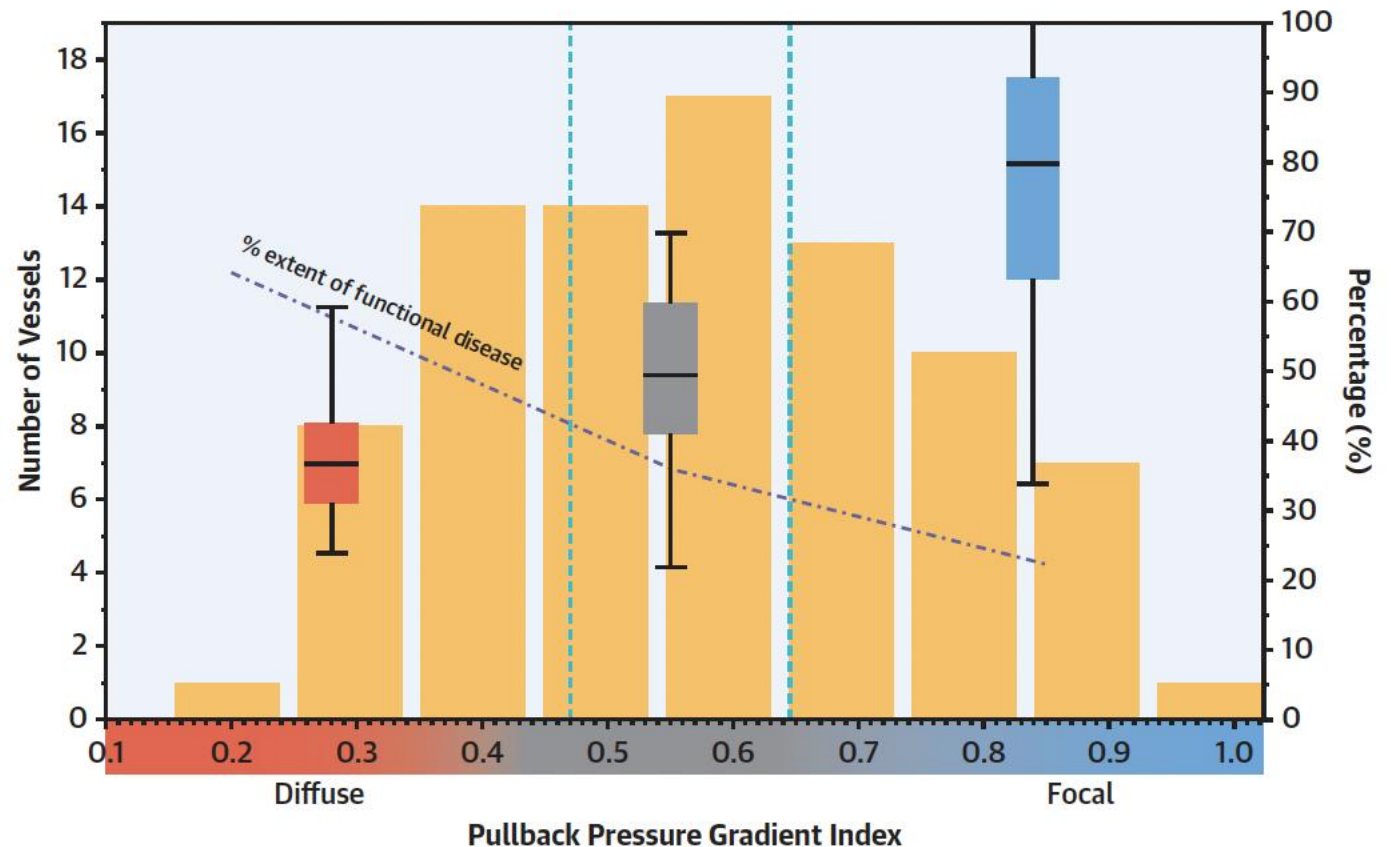
$$\frac{\left\{ \frac{MaxPPG_{20mm}}{\Delta FFR_{vessel}} + \left(1 - \frac{Length\ with\ functional\ disease\ (mm)}{Total\ vessel\ length\ (mm)} \right) \right\}}{2}$$

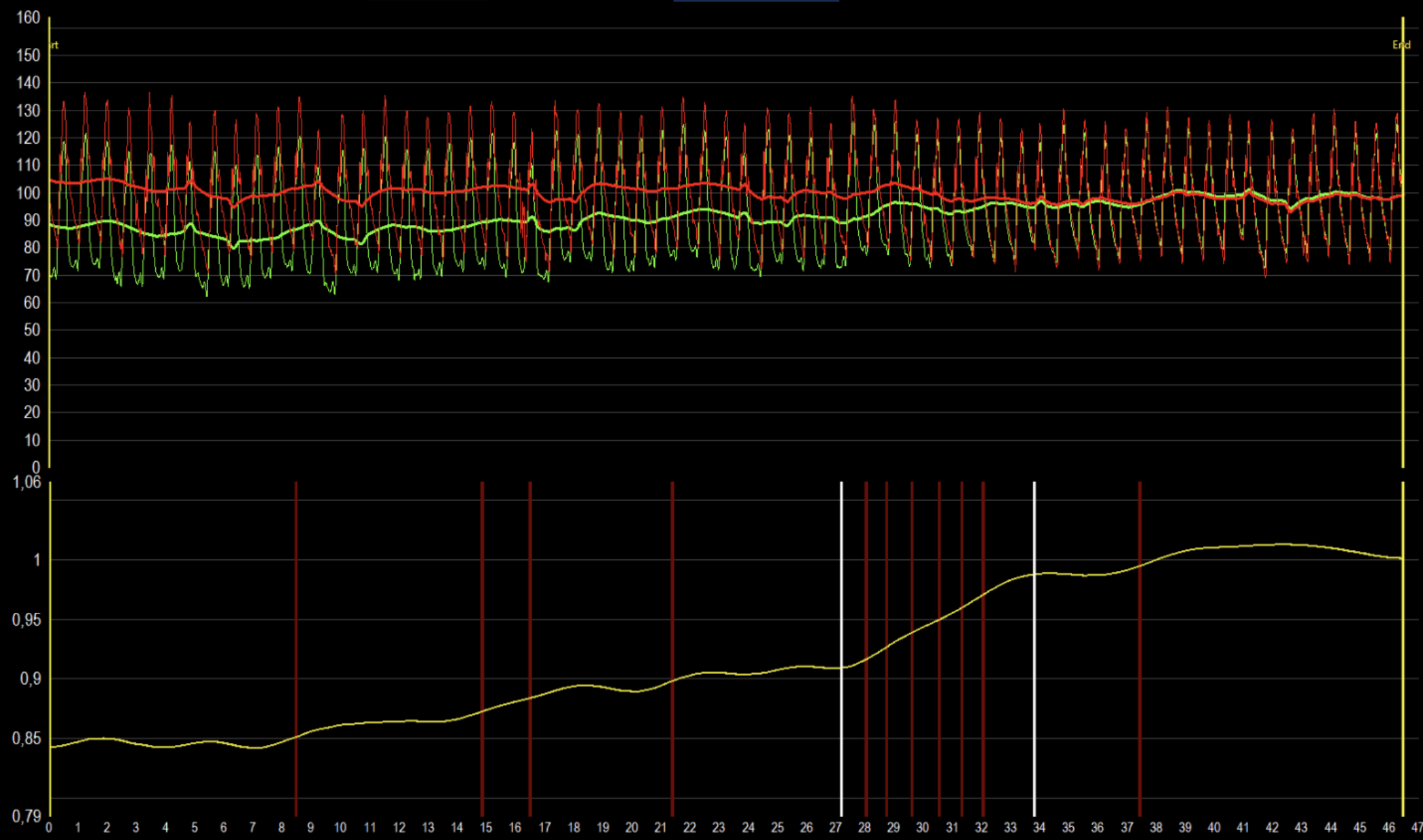
PPG = 1

- fokální postižení

PPG = 0

- difúzní postižení

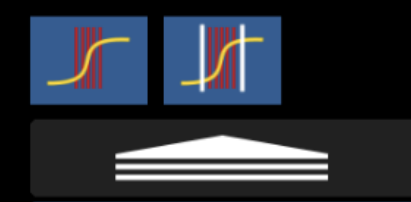




Start
0,85 89 Pd
105 Pa

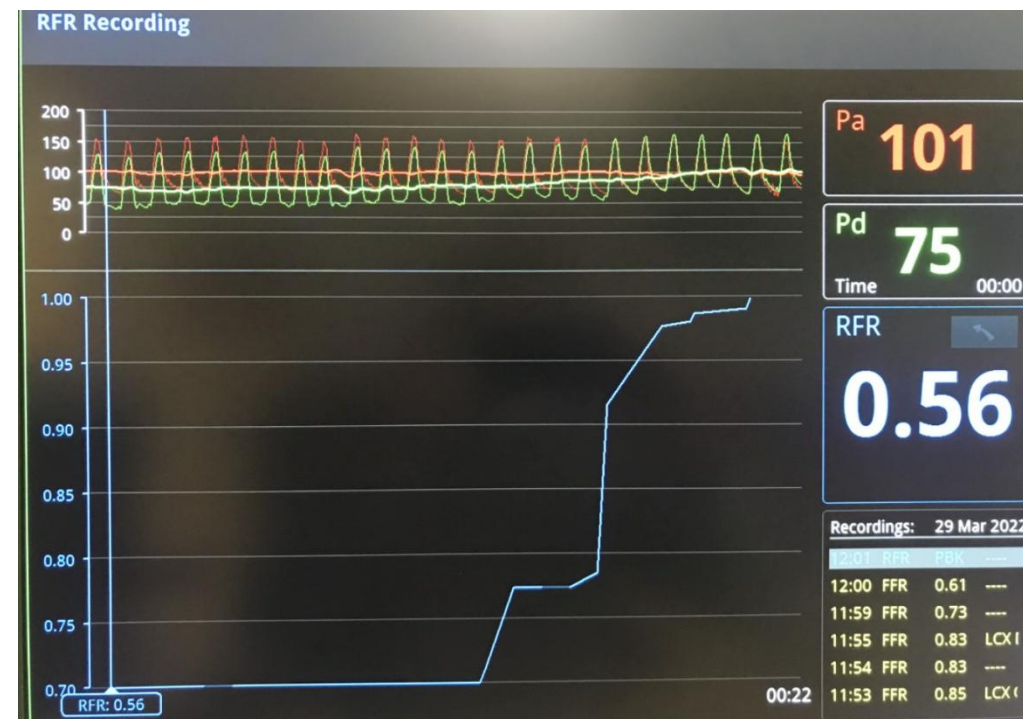
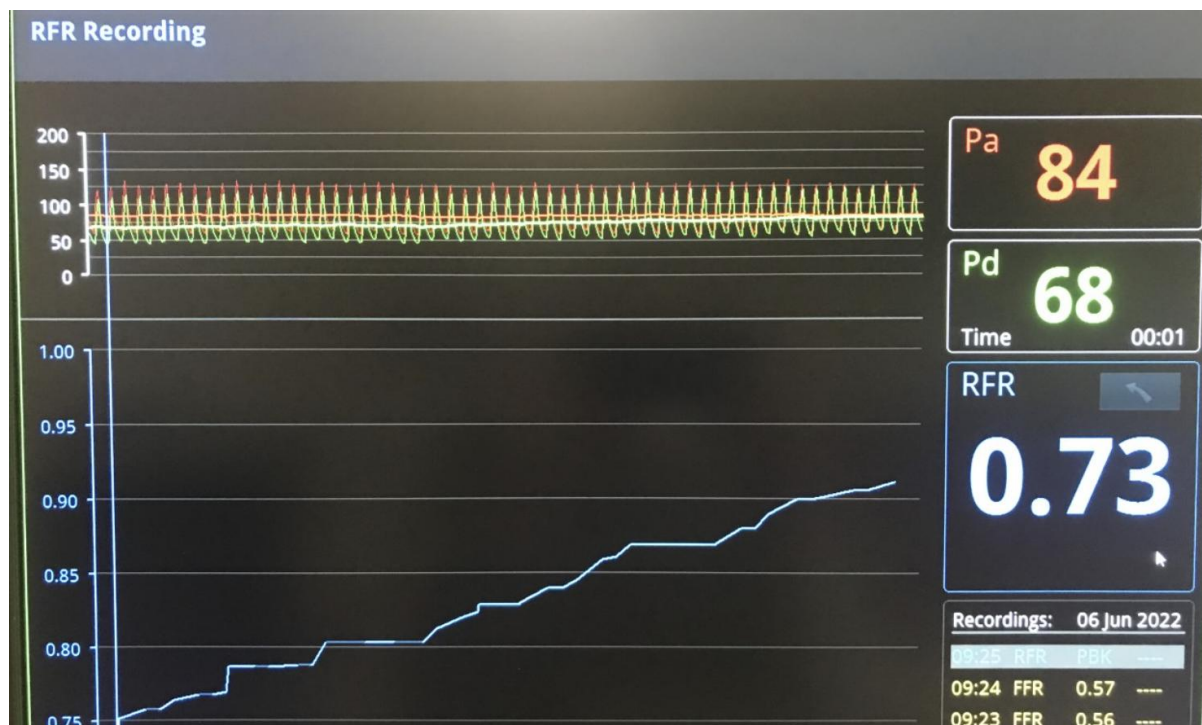
End
1,00 99 Pd
99 Pa

PPG
0,53 Δ 0,08
% 50

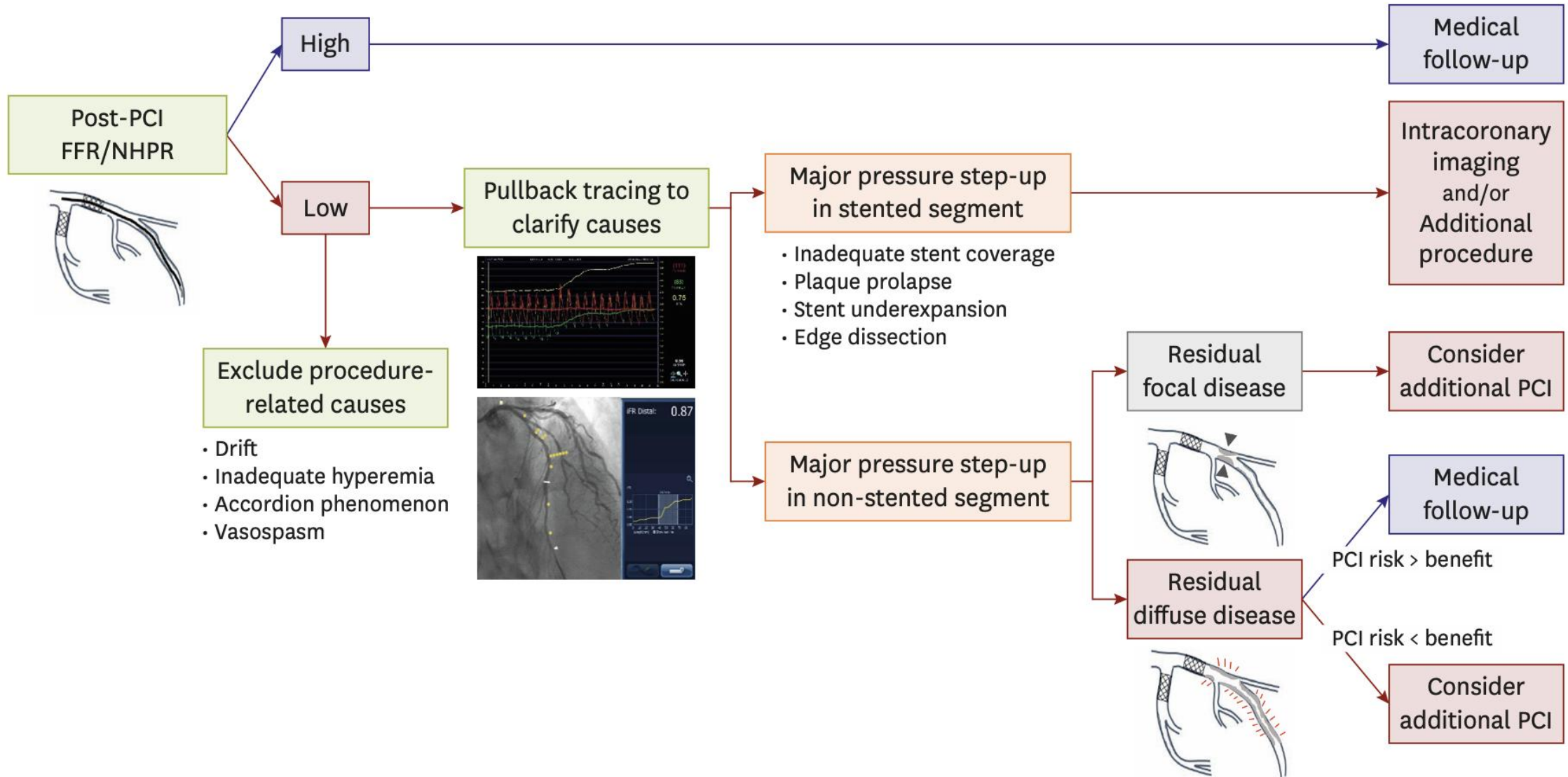


Live >

Pullback za použití klidových indexů

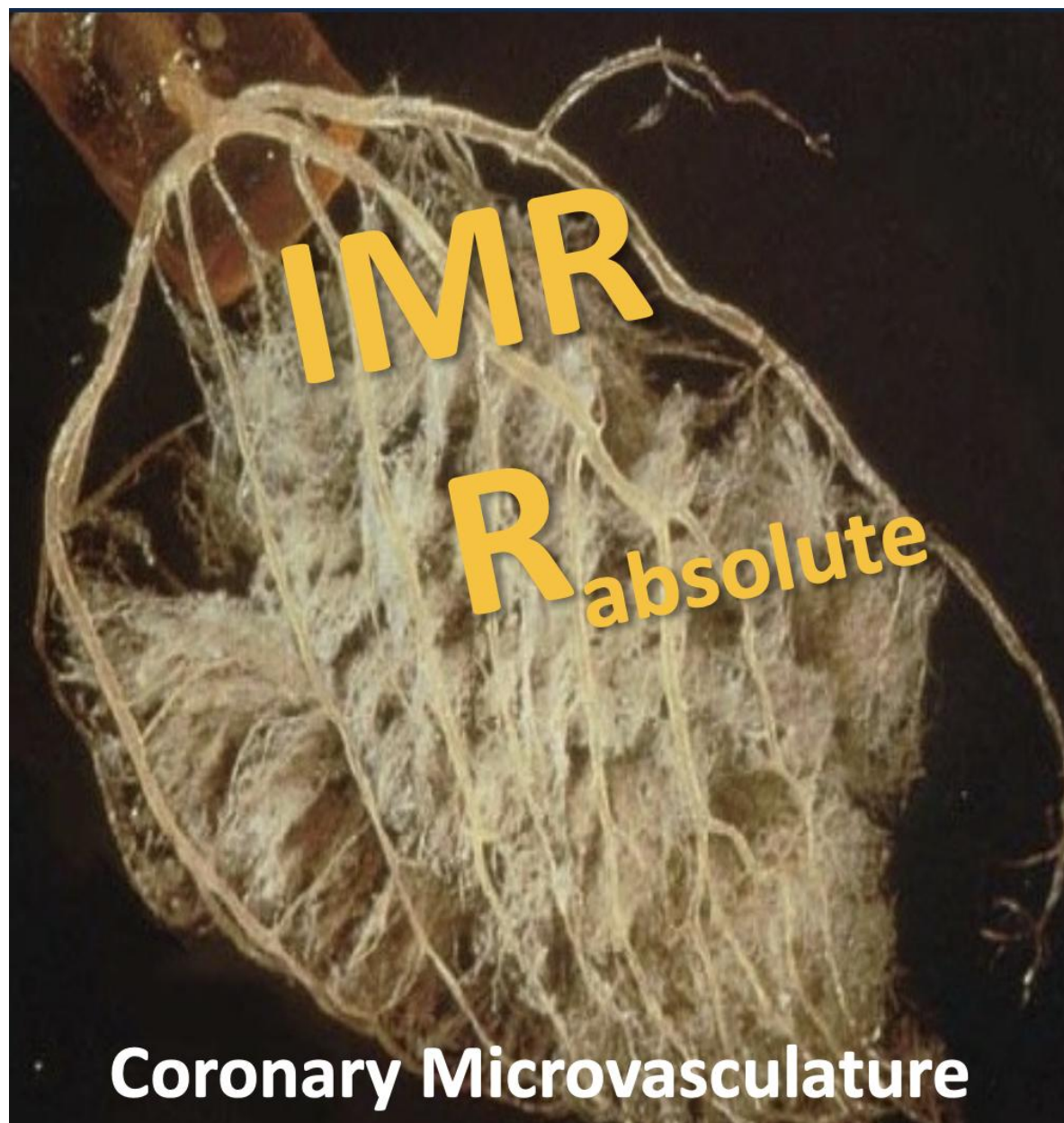


How to deal with low post-PCI FFR/NHI



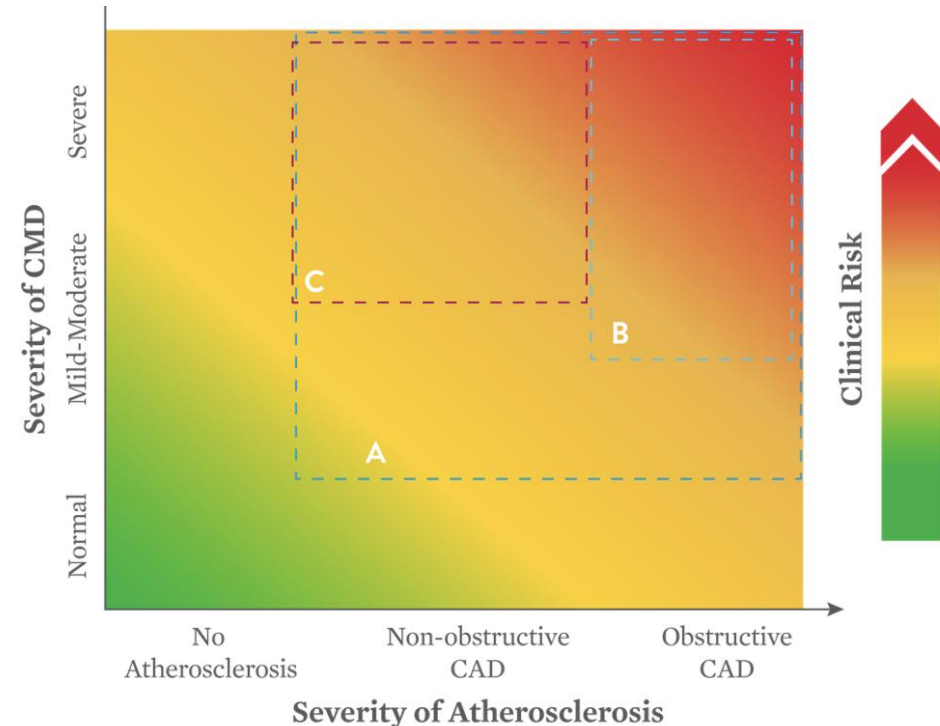
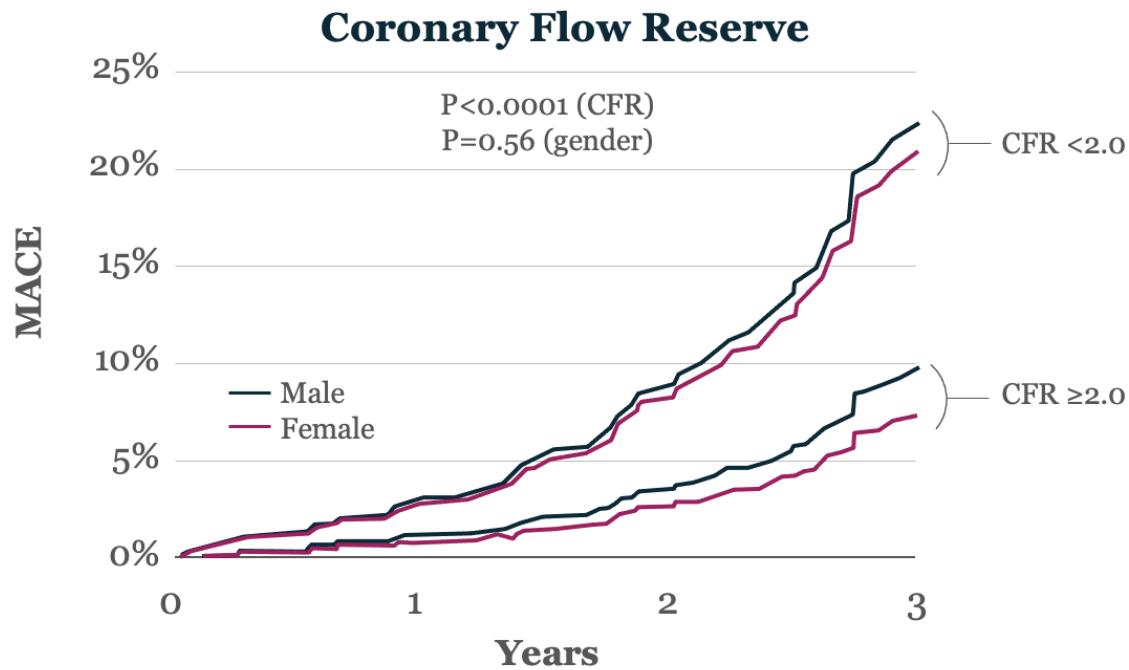


Mikrovaskulární
postižení



Coronary microvascular dysfunction (CMD)

- INOCA – ischemia caused by non-obstructive coronary artery disease



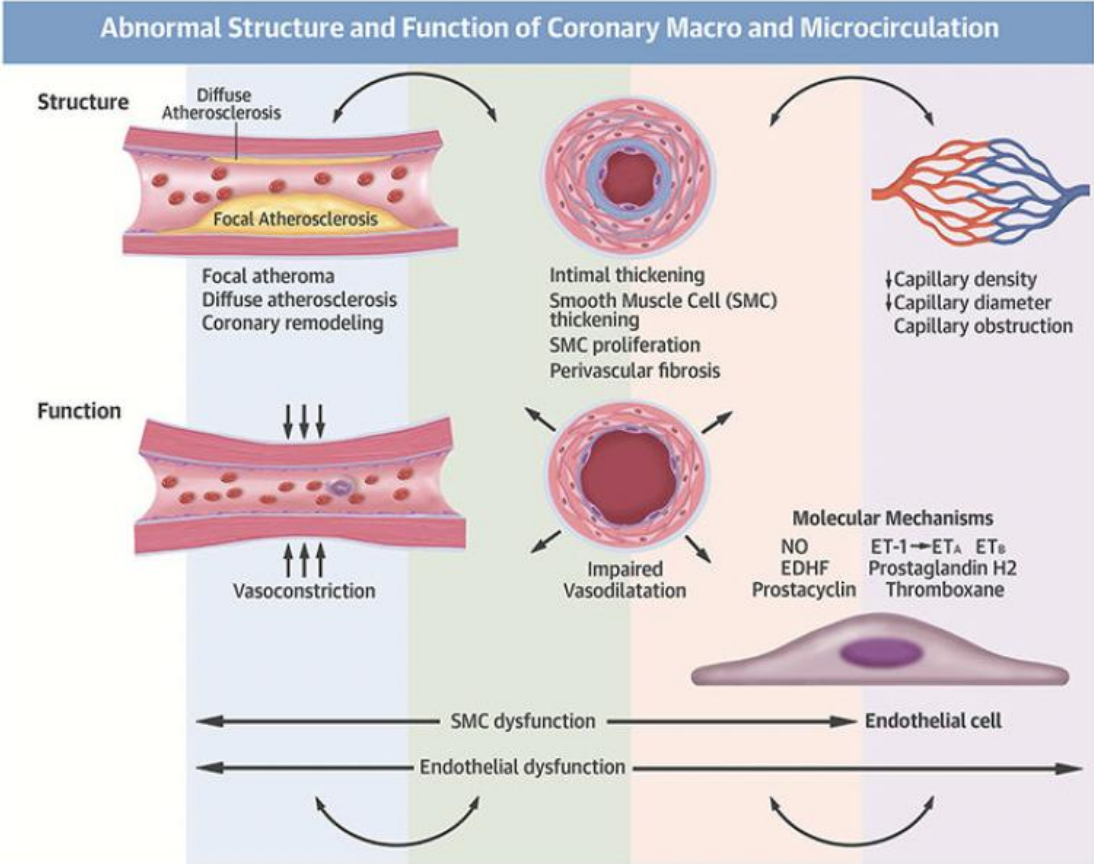
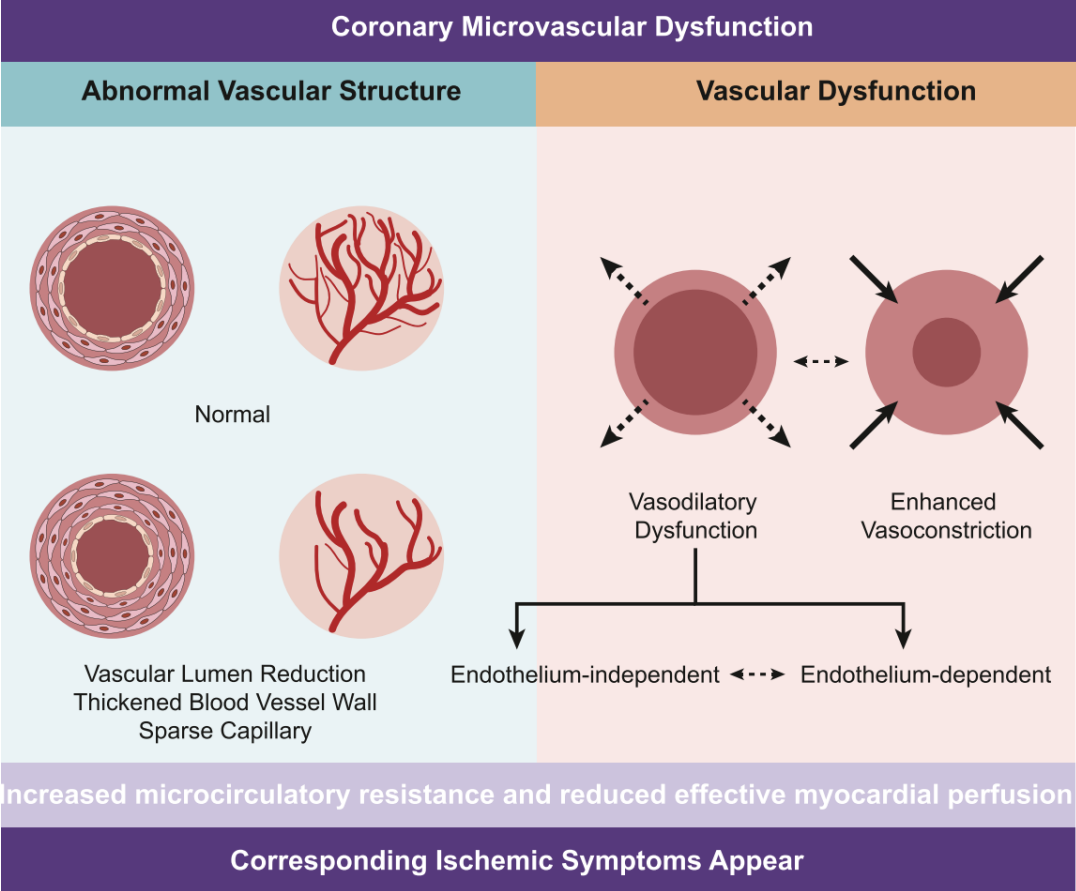
CFR/HSR/CFC should be considered as a complementary investigation; [359,360,366–368,376](#)

IIa

B

Taqueti. JACC 2018

Mikrovaskulární dysfunkce (CMD)



Výpočet koronární průtokové rezervy (CFR)

$$\text{CFR} = \frac{\text{F at hyperemia}}{\text{F at rest}}$$

$$\text{CFR} = \frac{\left(\frac{V}{T_{mn}}\right) \text{ at hyperemia}}{\left(\frac{V}{T_{mn}}\right) \text{ at rest}}$$

CFR > 2.0 mm = physiologic vascular function

Assuming the epicardial volume (V) remains unchanged, CFR can be calculated as follows.

$$(5) \quad \text{CFR} = \frac{T_{mn} \text{ at rest}}{T_{mn} \text{ at hyperemia}}$$

Výpočet intramyokardiální rezistence (IMR)

$$Q = P/R$$

$$R = P / Q$$

$$R = \frac{Pd - Pv}{V / Tmn}$$

$$R = \frac{Pd}{1 / Tmn}$$

$$IMR = Pd \times Tmn \text{ (mmHg x sec)}$$

$$Q = V / Tmn$$

$$V = 1$$
$$Pv = 0$$

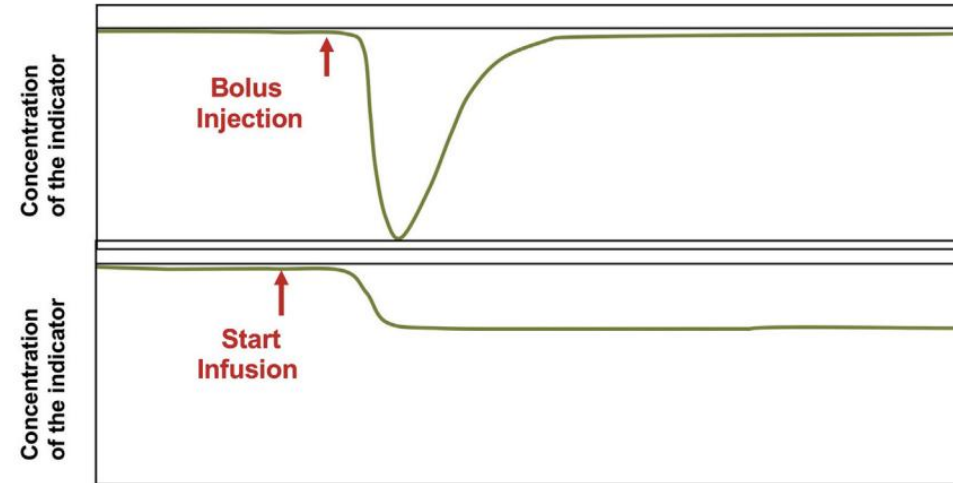
$$IMR_{uncor.} = Pd \cdot Tmn$$

$$IMR_{cor.} = Pa \cdot Tmn \cdot \left(\frac{Pd - Pw}{Pa - Pw} \right)$$

IMR > 25 mm (Hg x sec) = strukturální postižení mikrocirkulace



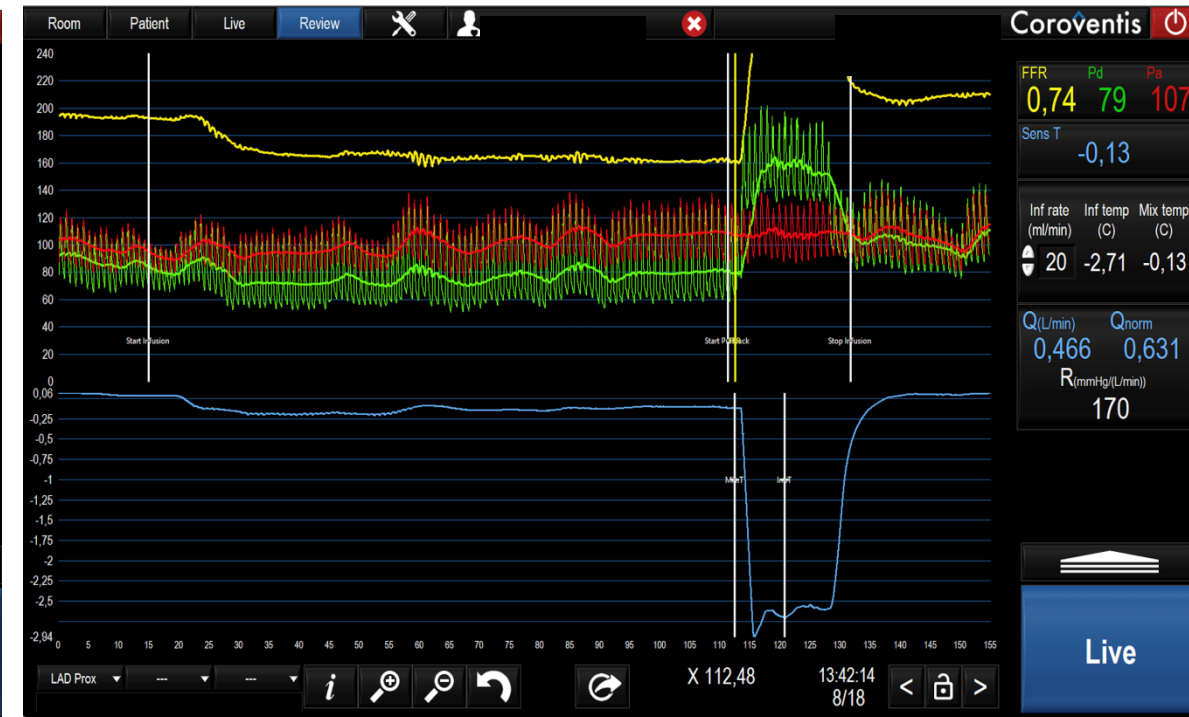
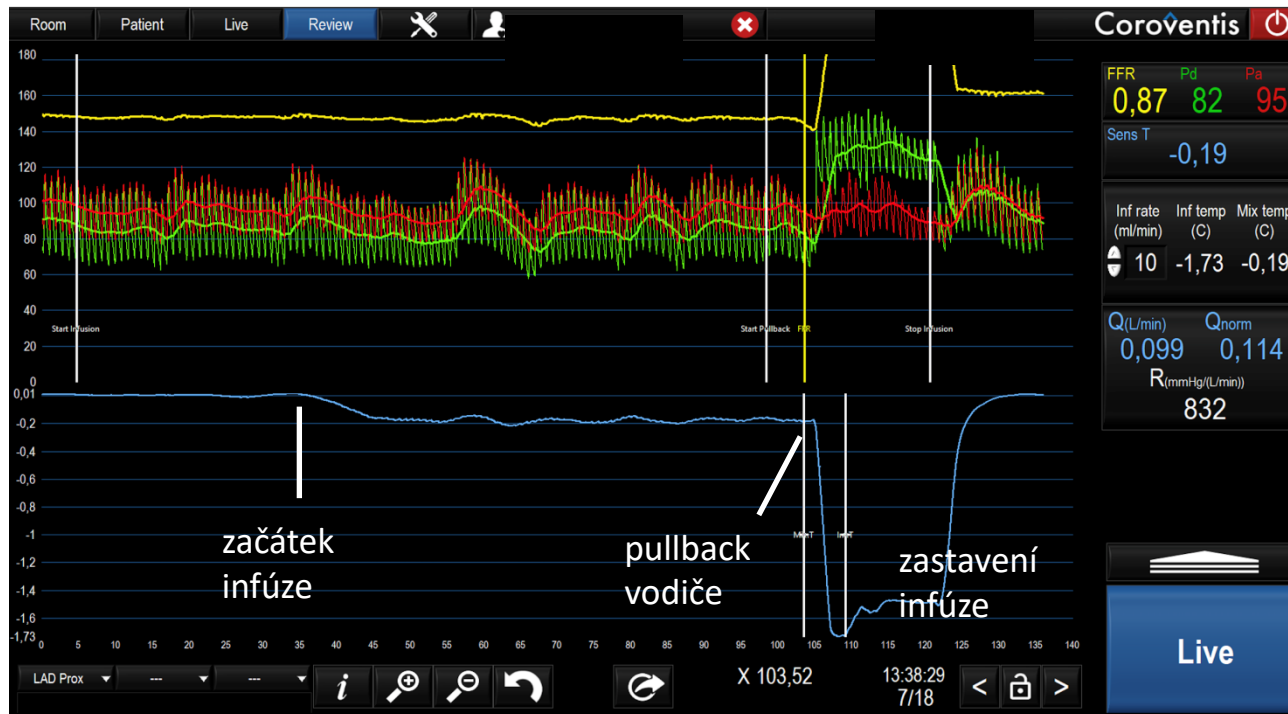
Meření absolutního průtoku



This block contains four distinct images. From left to right: 1. A long, thin, flexible catheter with a green handle, labeled 'Pressure WireX Abbott Vascular'. 2. A computer monitor displaying a software interface for 'Coroventis' with multiple data plots and numerical readouts, labeled 'Coroventis'. 3. A close-up of a hand holding a thin, dark catheter with a green marker, labeled 'Rayflow Catheter™ Hexacath, France'. 4. A white medical device with a screen and buttons, labeled 'Medrad Infusion Pump'.

Měření absolutního průtoku a absolutní resistance

- bez adenosinu, za kontinuální infuze FR do koronární tepny

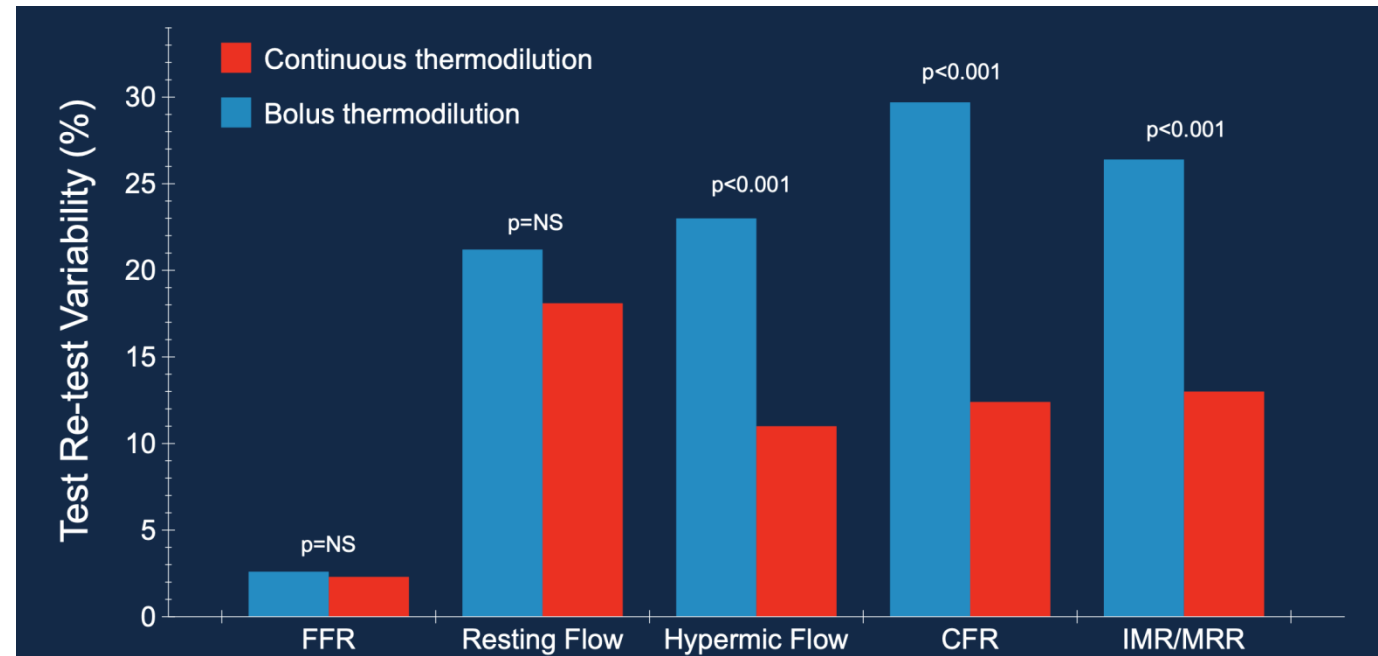
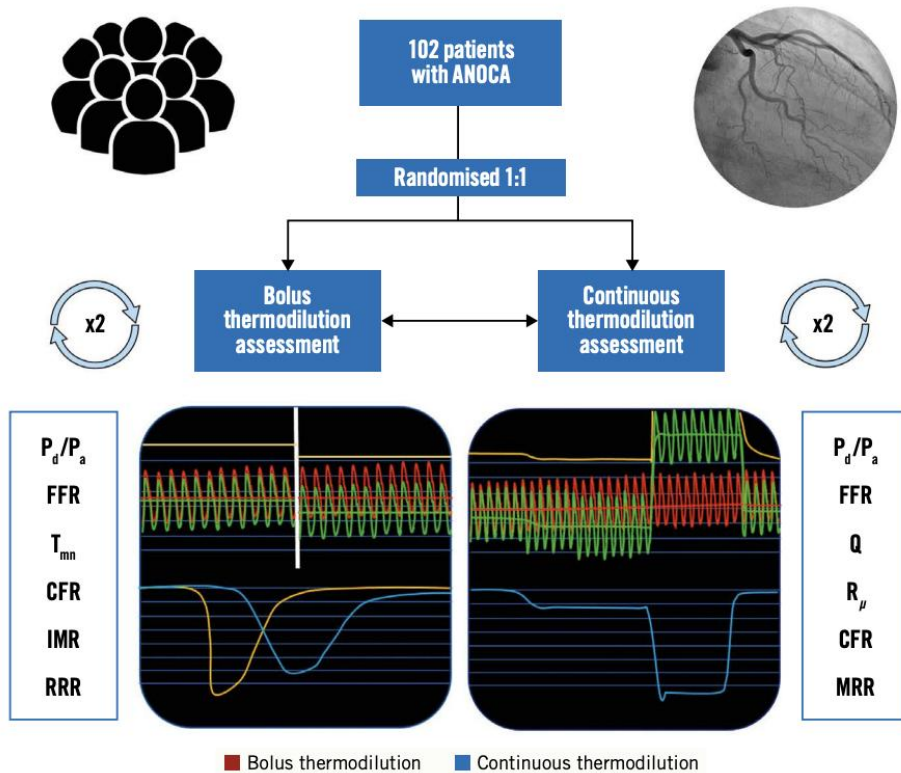


$$CFR = Q_{max} / Q_{rest}$$

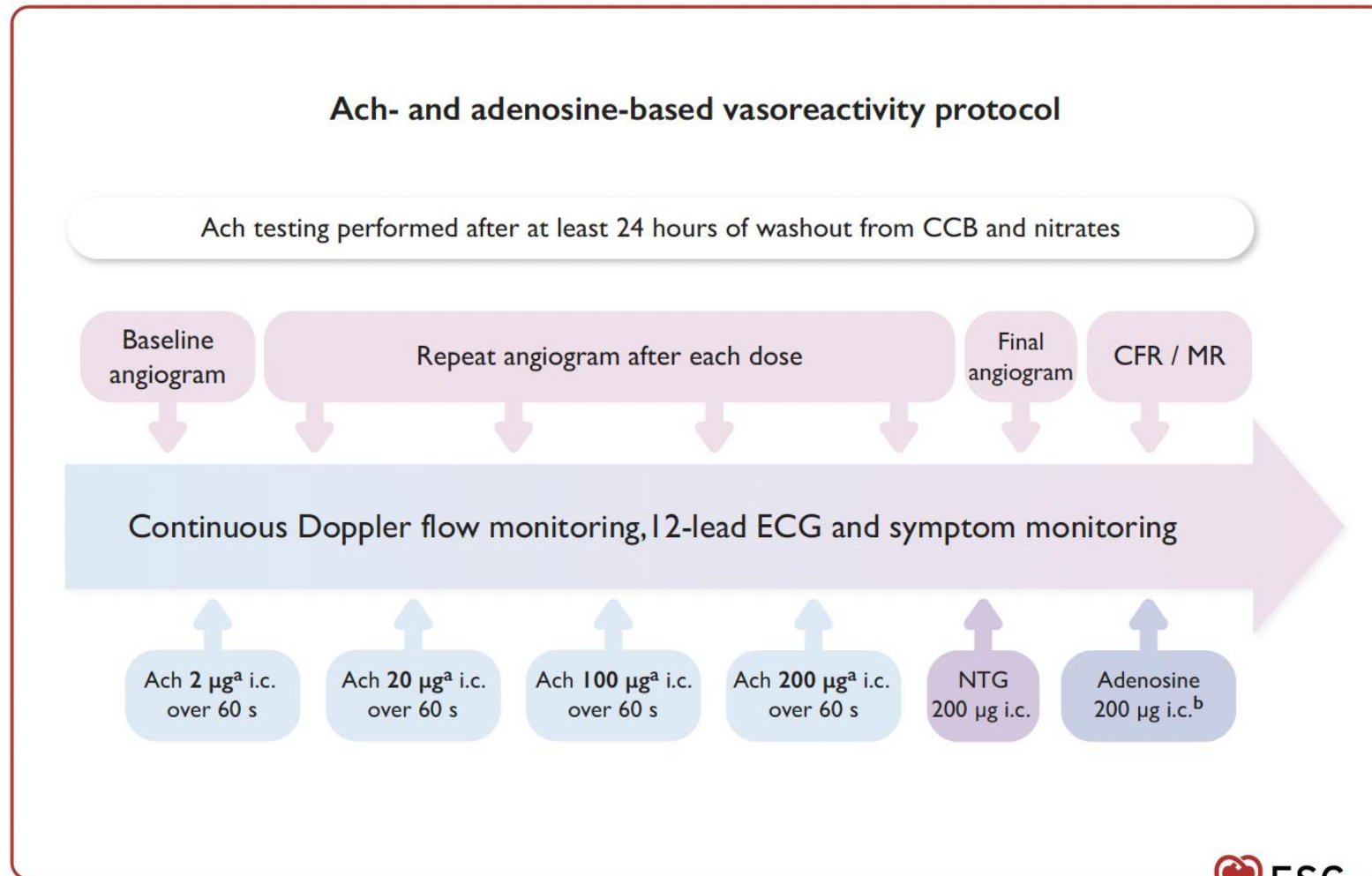
$$MRR = \frac{Q_{max}}{Q_{rest}} \cdot \frac{P_{a,hyp}}{P_{d,hyp}} \cdot \frac{P_{d,rest}}{P_{a,rest}}$$

MRR < 2.5-2.7 – mikrovaskulární dysfunkce

Bolusová vs kontinuální termodiluce



Testování vasoreaktivity prostřednictvím i.c. podání acetylcholinu



🫀 Effect of Acetylcholine on Coronary Perfusion

Dual (Paradoxical) Effect Depending on Endothelial Function

✅ Normal Endothelium

- Acetylcholine stimulates M3 receptors on endothelium
- → Release of nitric oxide (NO)
- → Vasodilation of coronary arteries
- → ↑ Coronary blood flow (perfusion)

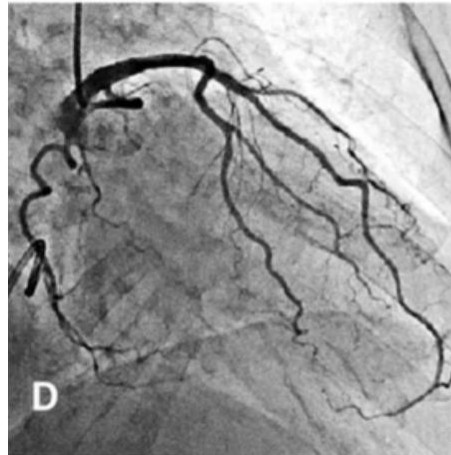
👉 Result: Improved myocardial perfusion

⚠️ Endothelial Dysfunction

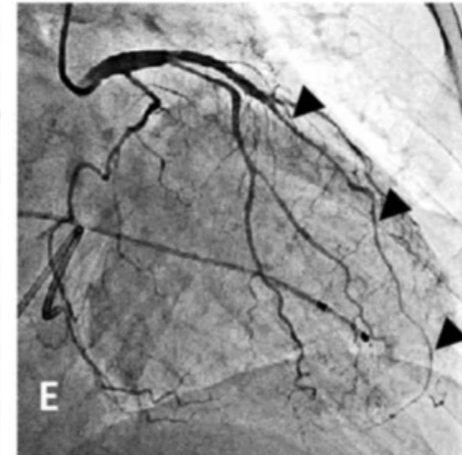
- Impaired NO production
- Acetylcholine acts directly on vascular smooth muscle
- → Vasoconstriction / coronary spasm
- → ↓ Coronary perfusion

👉 Result: Myocardial ischemia (e.g., vasospastic angina)

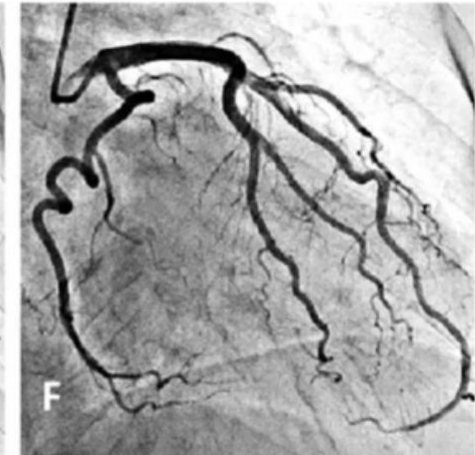
Diffuse spasm pattern



Control CAG



Acetylcholine 100µg

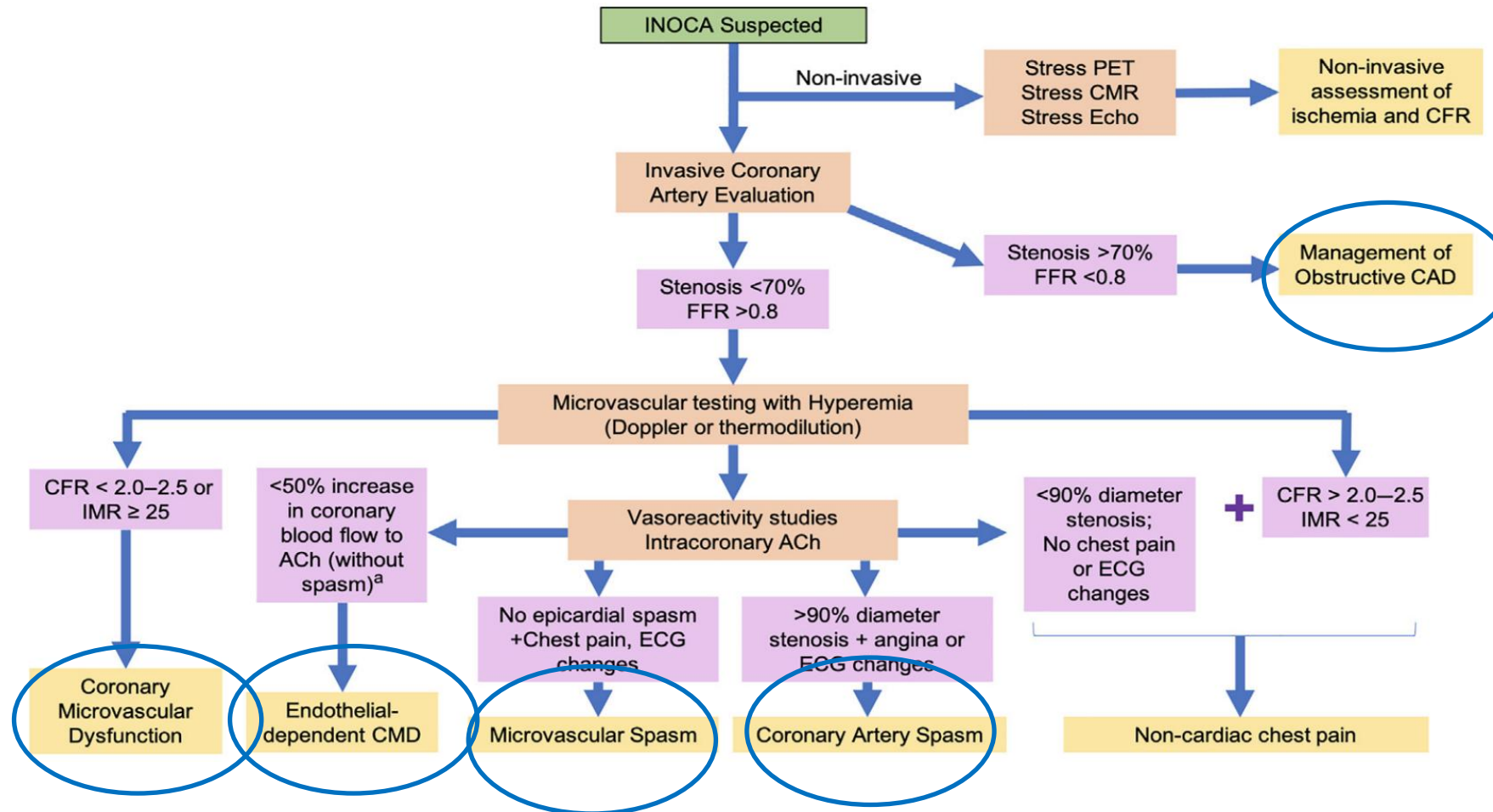


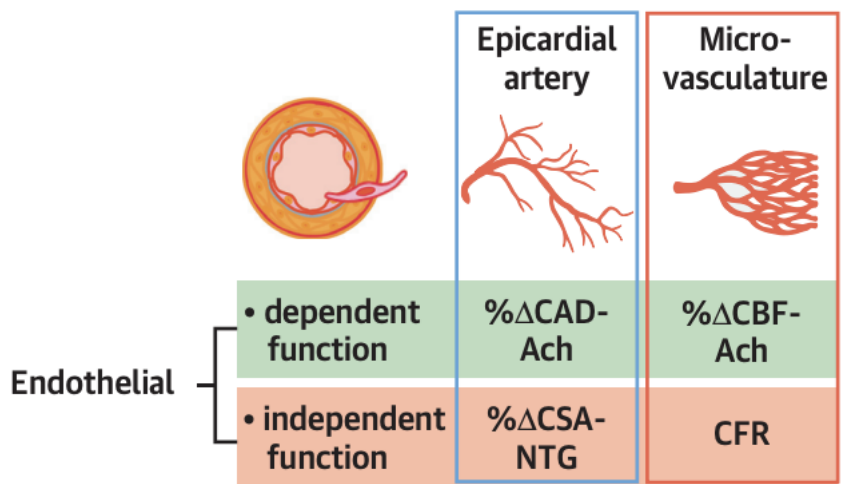
Nitroglycerin

Sato K. JAHA 2013;e000227

Beyond Coronary Artery Disease

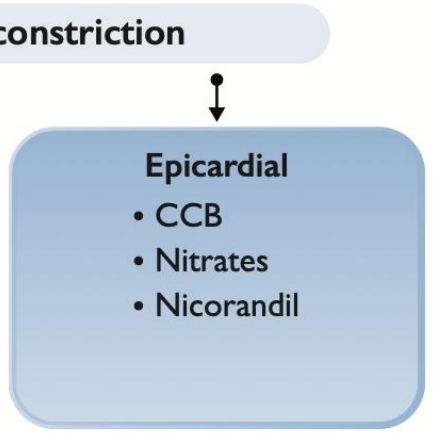
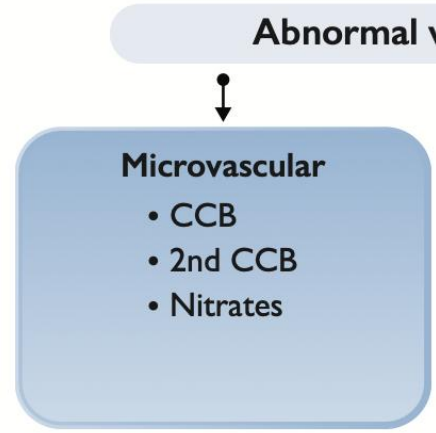
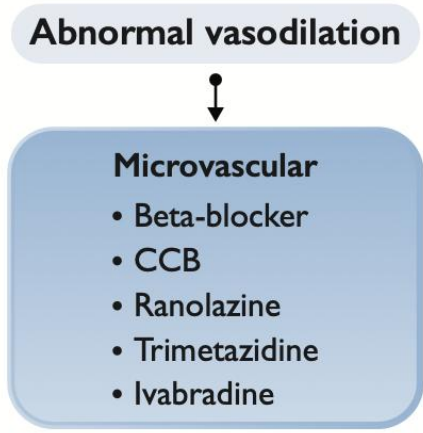
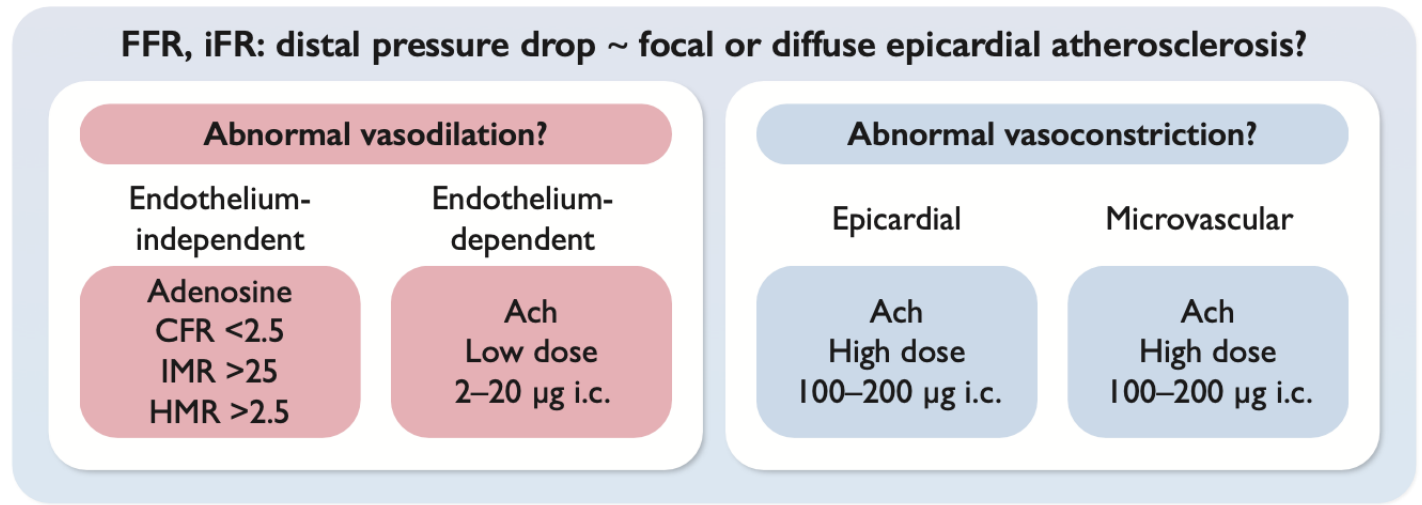
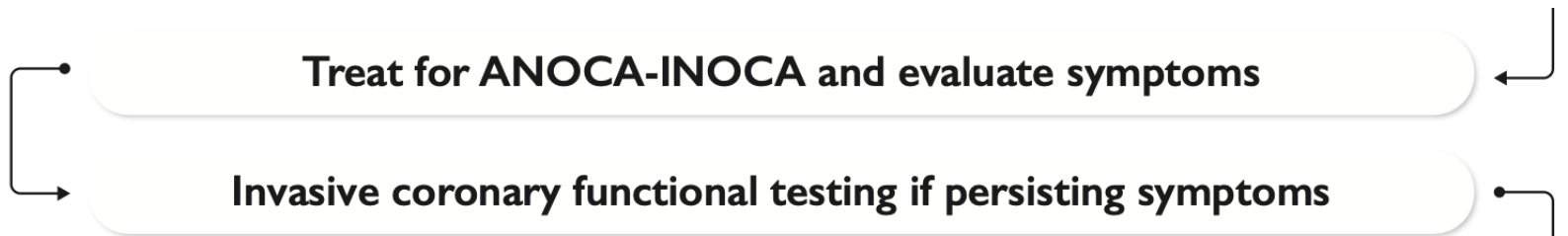
Assessing the Microcirculation





Kanaji Y, et al. J Am Coll Cardiol Interv. 2024;17(4):474-487.

Treatment of ANOCA/INOCA






DAVID WORRENT

Závěr


Invazivní funkční vyšetření má třídu doporučení IA pro intermediální stenózy v aktuálních ESC doporučení



Komplexní vyšetření zahrnující vyšetření koronární mikrocirkulace má úroveň doporučení IIA



Je patrna renesance testování koronární vasoreaktivity za použití intrakoronární aplikace acetylcholinu



Zásadním problémem zůstává terapeutický přístup u pacientů s prokázanou mikrovaskulární dysfunkcí

WORKSHOP OCT FFR / iFR NIRS IVUS

Akce konaná pod záštitou České asociace intervenční kardiologie

16. ročník – únor 2027 CINRE Bratislava

