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Hodnocení významnosti koronárních stenóz

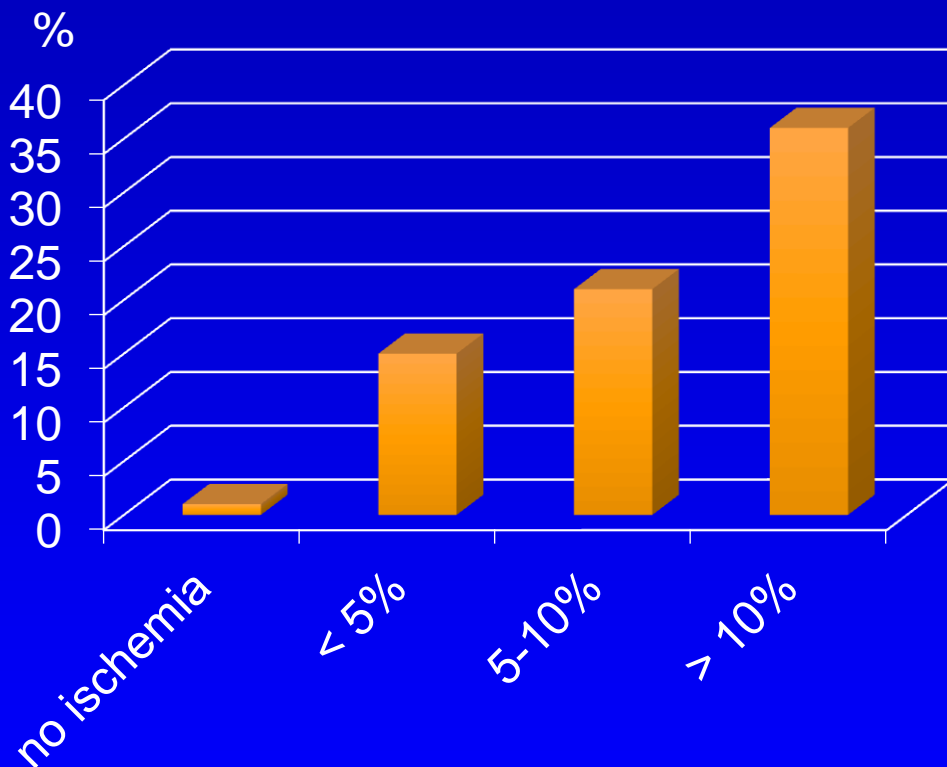
Tomáš Kovárník



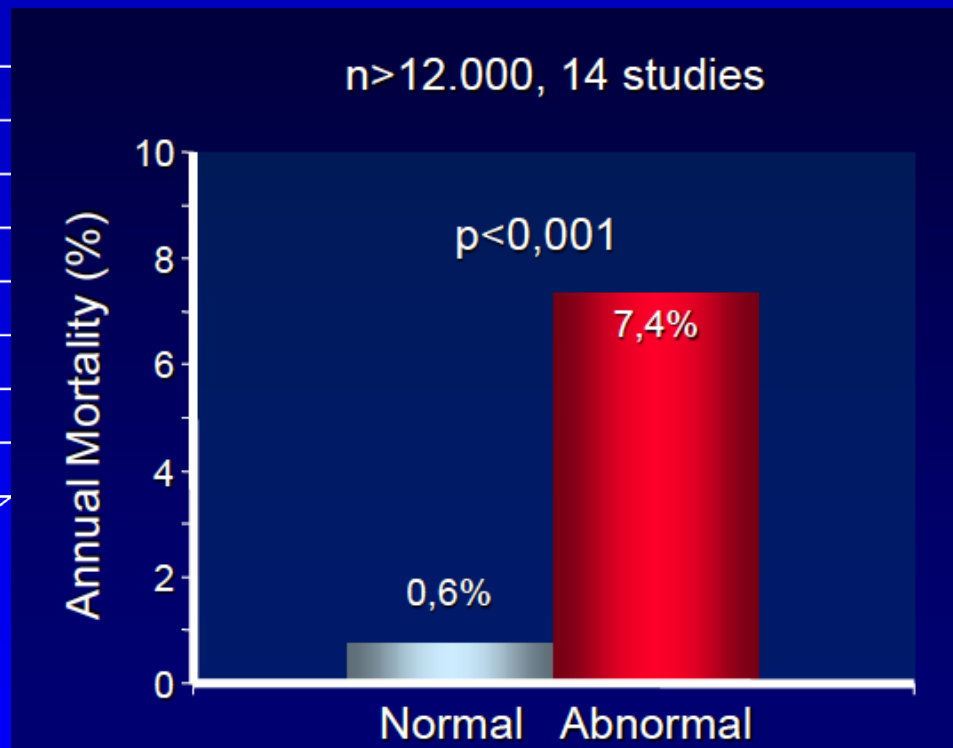
II. interní klinika
kardiologie a angiologie
VFN a 1. LF UK
Praha



Prognóza pacientů podle přítomnosti myokardiální ischemie hodnocené pomocí SPECT



Shaw. Circulation 2008;117:1283



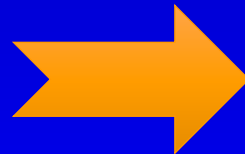
Iskander S. JACC 1998



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Posun paradigmatu

Stabilní
angina
pectoris

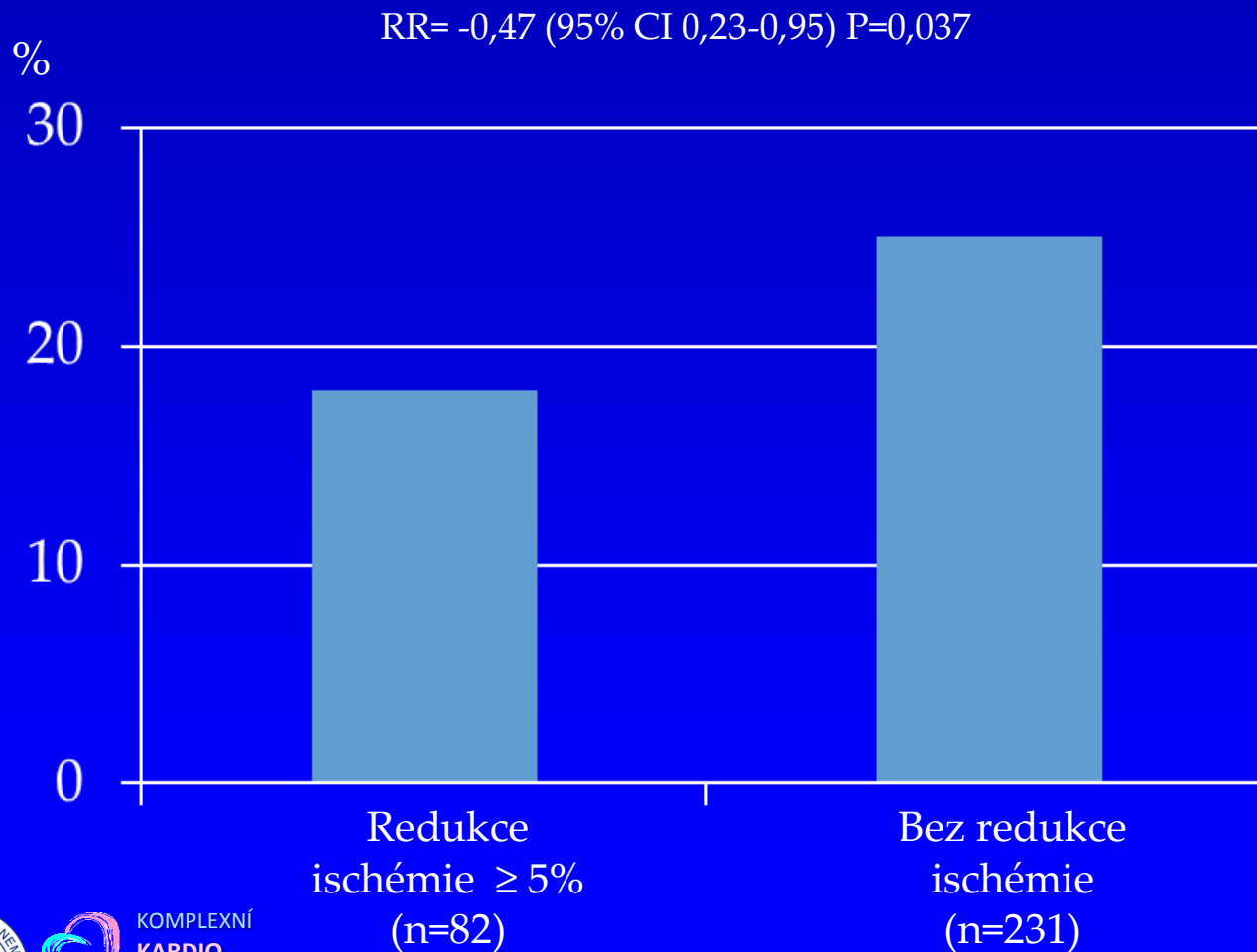


Rozsah
ischemie
myokardu



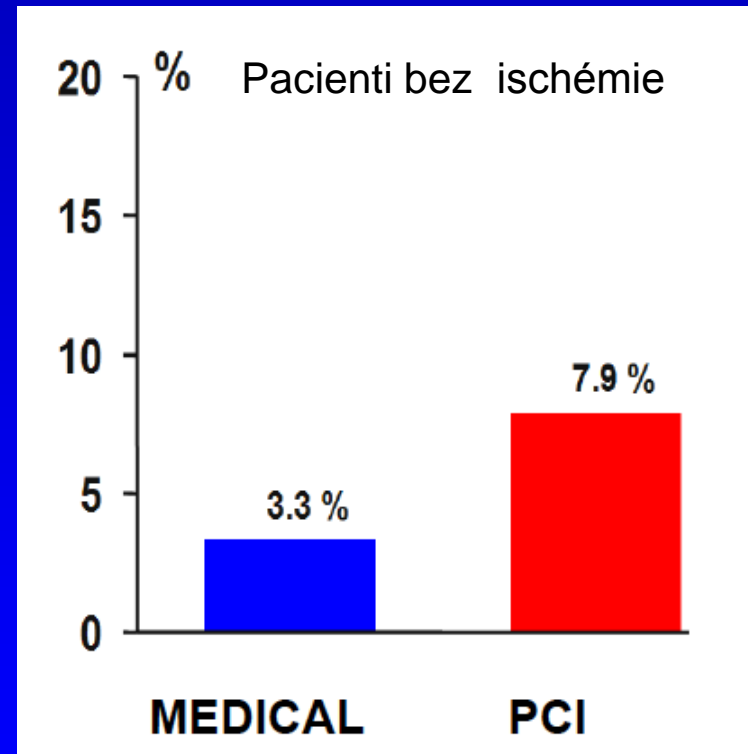
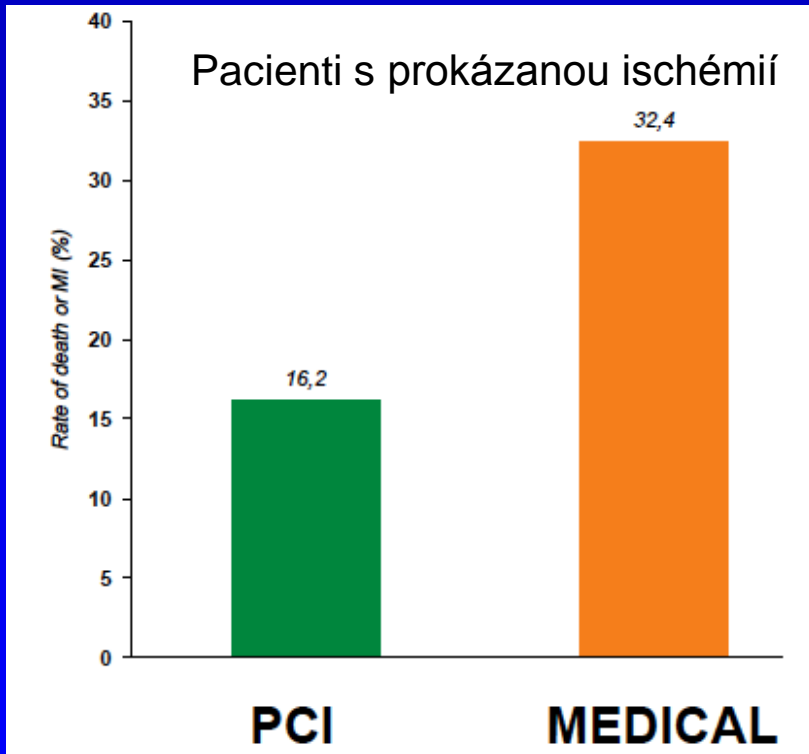
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Vliv snížení rozsahu ischemie myokardu na mortalitu pacientů se SAP - subanalýza studie COURAGE -



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Úmrtí a vznik IM ve vztahu k přítomnosti ischemie



Shaw. Circulation 2008

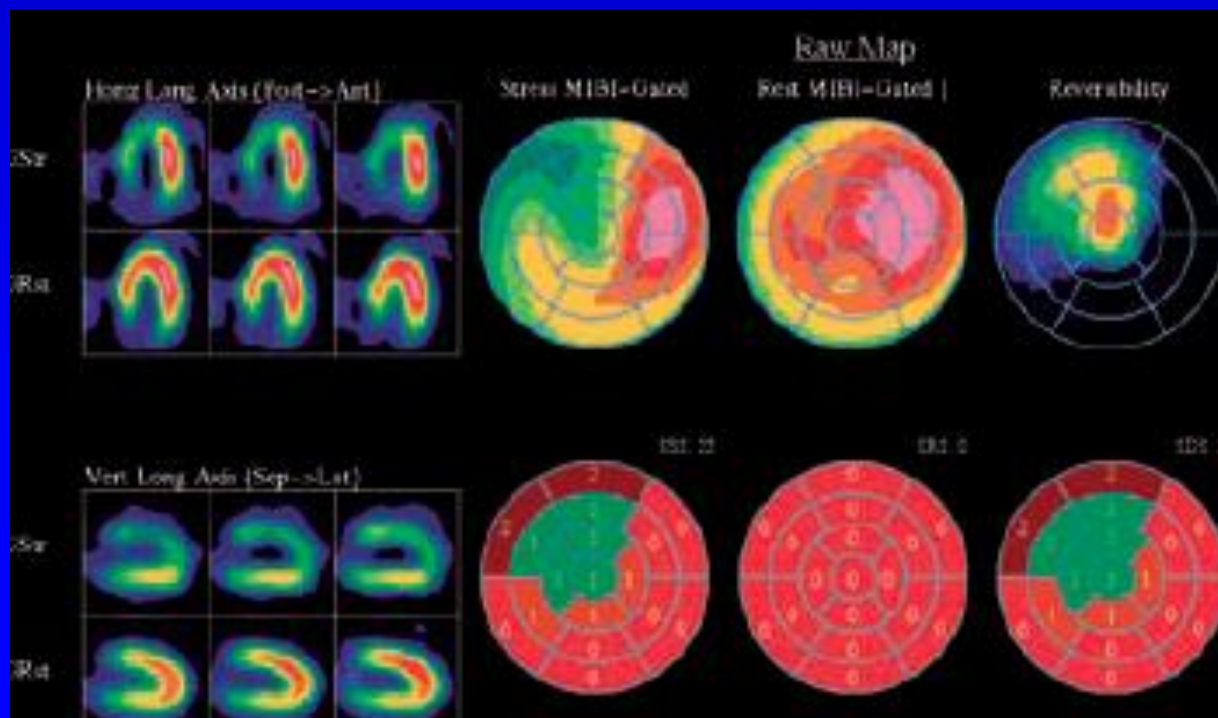
Pijls N. Shaw. JACC 2007



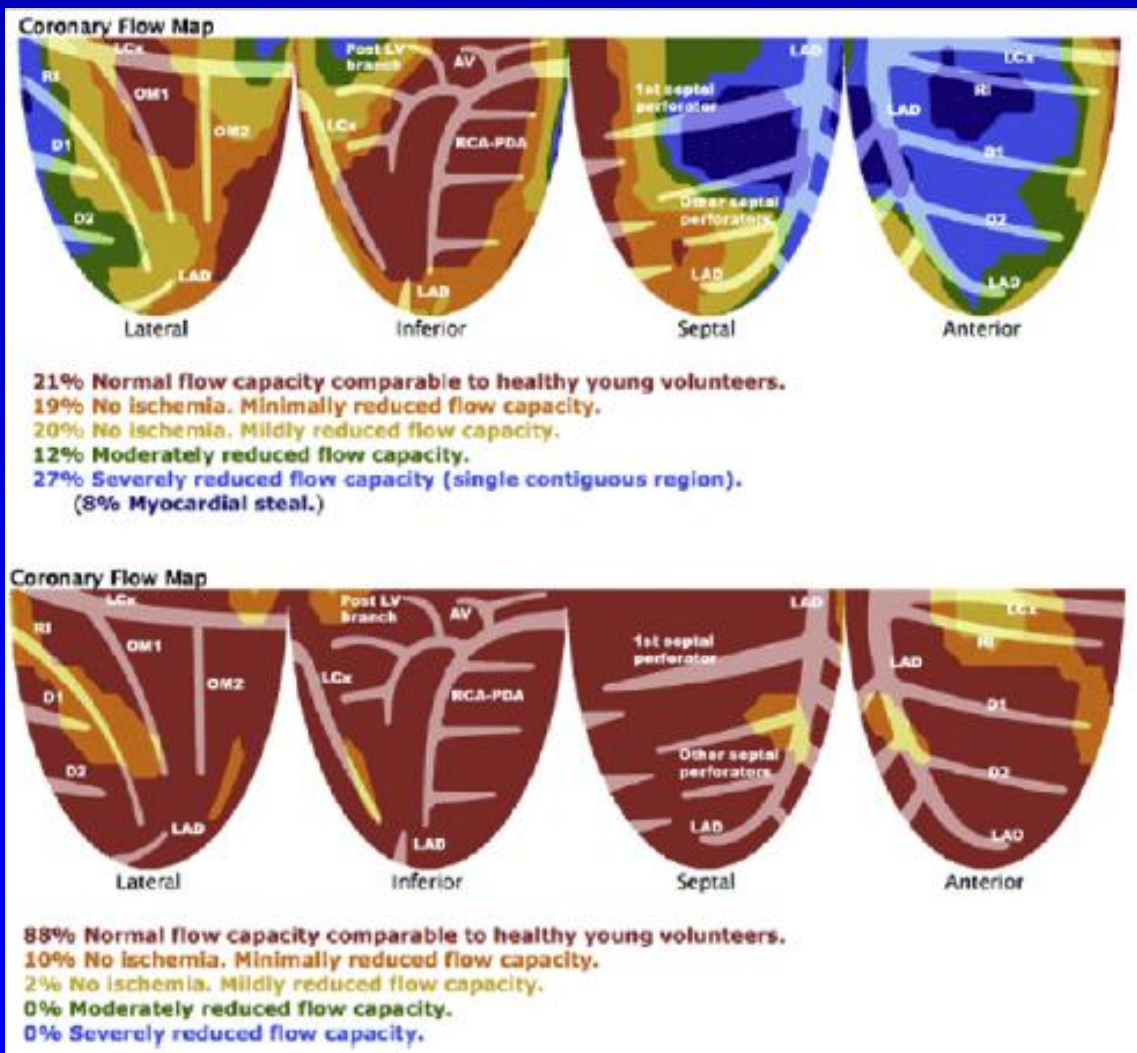
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Detekce myokardiální ischemie

- Perfúzní scintigrafie myokardu – SPECT
- Pozitronová emisní tomografie – PET
- CT FFR



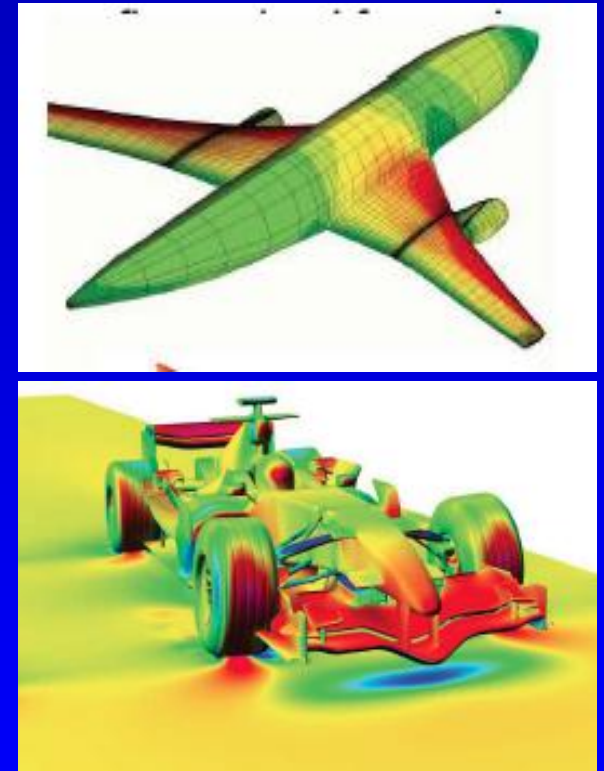
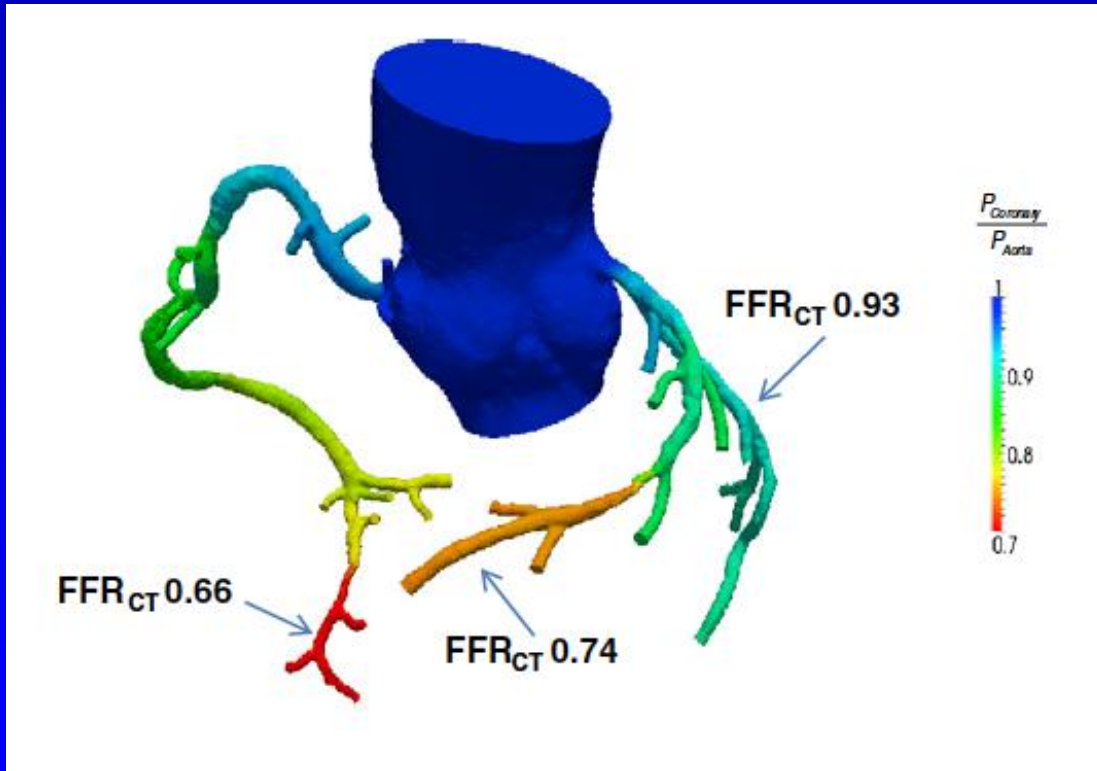
Diagnostika ischemie myokardu pomocí PET



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Gould L. JACC 21013;62: 1639-53

Neinvazivní hodnocení FFR pomocí CT



Navier-Stokes rovnice

$$r: \rho \left(\frac{\partial u_r}{\partial t} + u_r \frac{\partial u_r}{\partial r} + \frac{u_\phi}{r \sin \theta} \frac{\partial u_r}{\partial \phi} + \frac{u_\theta}{r} \frac{\partial u_r}{\partial \theta} - \frac{u_\phi^2 + u_\theta^2}{r} \right) =$$

$$= -\frac{\partial p}{\partial r} + \rho g_r + \mu \left(\frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial u_r}{\partial r} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 u_r}{\partial \phi^2} + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial u_r}{\partial \theta} \right) - 2 \frac{u_r + \frac{\partial u_\theta}{\partial \theta} + u_\theta \cot \theta}{r^2} - \frac{2}{r^2 \sin \theta} \frac{\partial u_\phi}{\partial \phi} \right)$$

$$\phi: \rho \left(\frac{\partial u_\phi}{\partial t} + u_r \frac{\partial u_\phi}{\partial r} + \frac{u_\phi}{r \sin \theta} \frac{\partial u_\phi}{\partial \phi} + \frac{u_\theta}{r} \frac{\partial u_\phi}{\partial \theta} + \frac{u_r u_\phi + u_\phi u_\theta \cot \theta}{r} \right) =$$

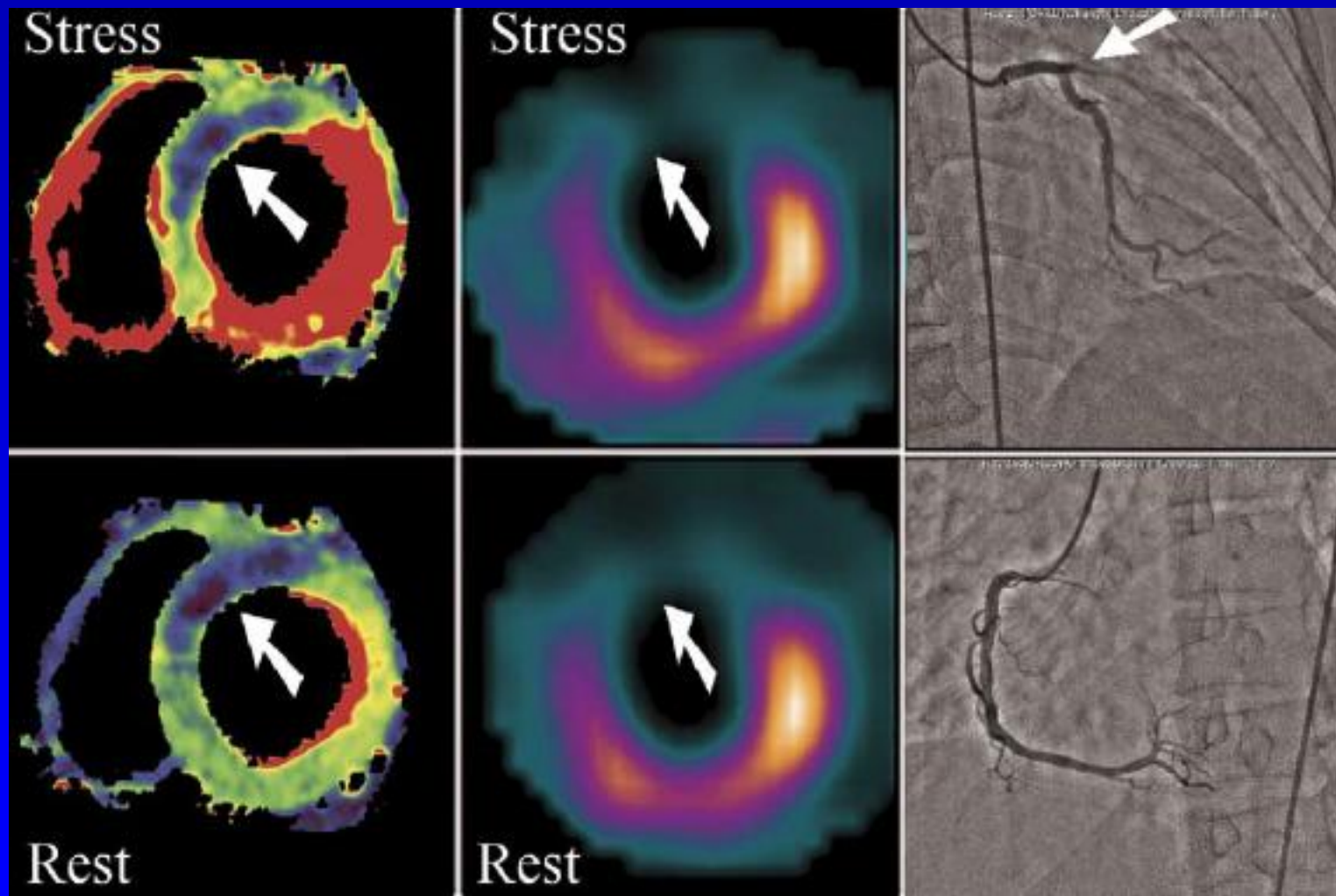
$$= -\frac{1}{r \sin \theta} \frac{\partial p}{\partial \phi} + \rho g_\phi + \mu \left(\frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial u_\phi}{\partial r} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 u_\phi}{\partial \phi^2} + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial u_\phi}{\partial \theta} \right) + \frac{2 \sin \theta \frac{\partial u_r}{\partial \phi} + 2 \cos \theta \frac{\partial u_\theta}{\partial \phi} - u_\phi}{r^2 \sin^2 \theta} \right)$$

$$\theta: \rho \left(\frac{\partial u_\theta}{\partial t} + u_r \frac{\partial u_\theta}{\partial r} + \frac{u_\phi}{r \sin \theta} \frac{\partial u_\theta}{\partial \phi} + \frac{u_\theta}{r} \frac{\partial u_\theta}{\partial \theta} + \frac{u_r u_\theta - u_\phi^2 \cot \theta}{r} \right) =$$

$$= -\frac{1}{r} \frac{\partial p}{\partial \theta} + \rho g_\theta + \mu \left(\frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial u_\theta}{\partial r} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 u_\theta}{\partial \phi^2} + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial u_\theta}{\partial \theta} \right) + \frac{2}{r^2} \frac{\partial u_r}{\partial \theta} - \frac{u_\theta + 2 \cos \theta \frac{\partial u_\phi}{\partial \phi}}{r^2 \sin^2 \theta} \right).$$



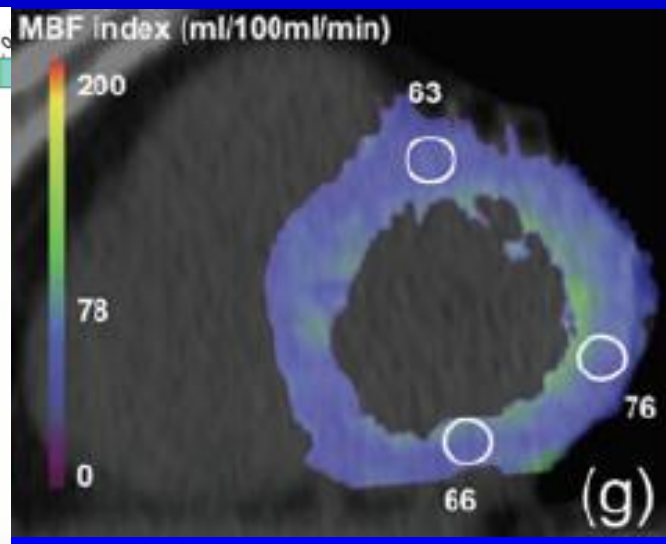
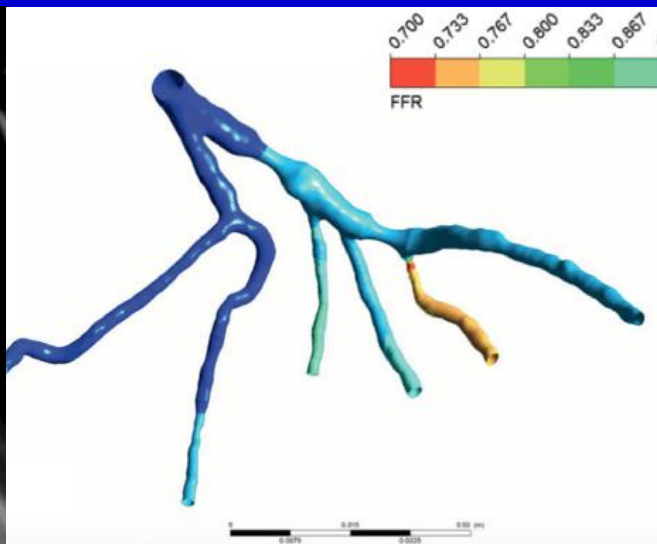
CT hodnocení myokardiální perfúze



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Ho KT. JACC CV Img. 2010;3:811-20

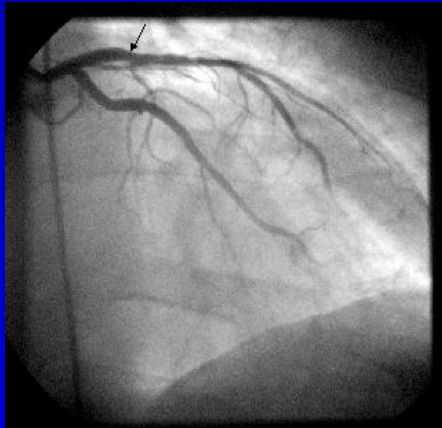
Dear Santa,
I want it all!



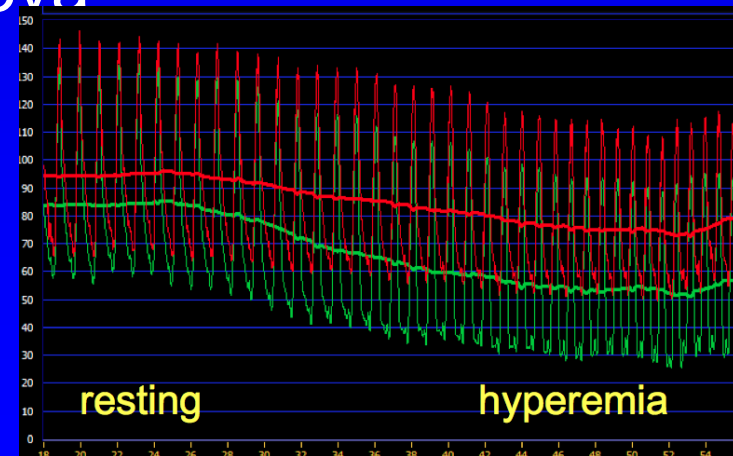
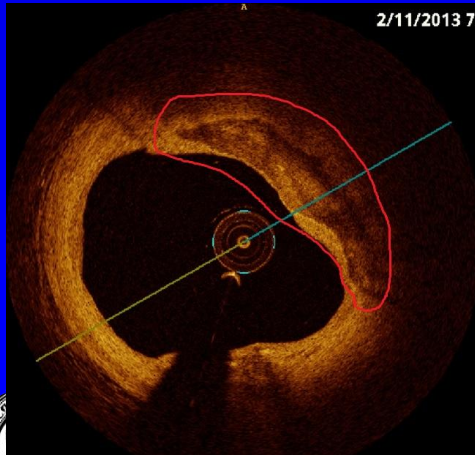
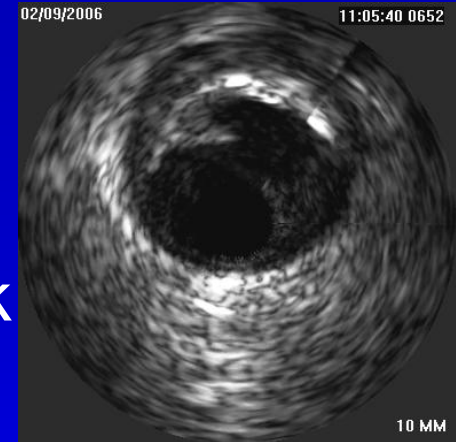
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Rossi A. EHJ CV Img. 2014;15:85-94

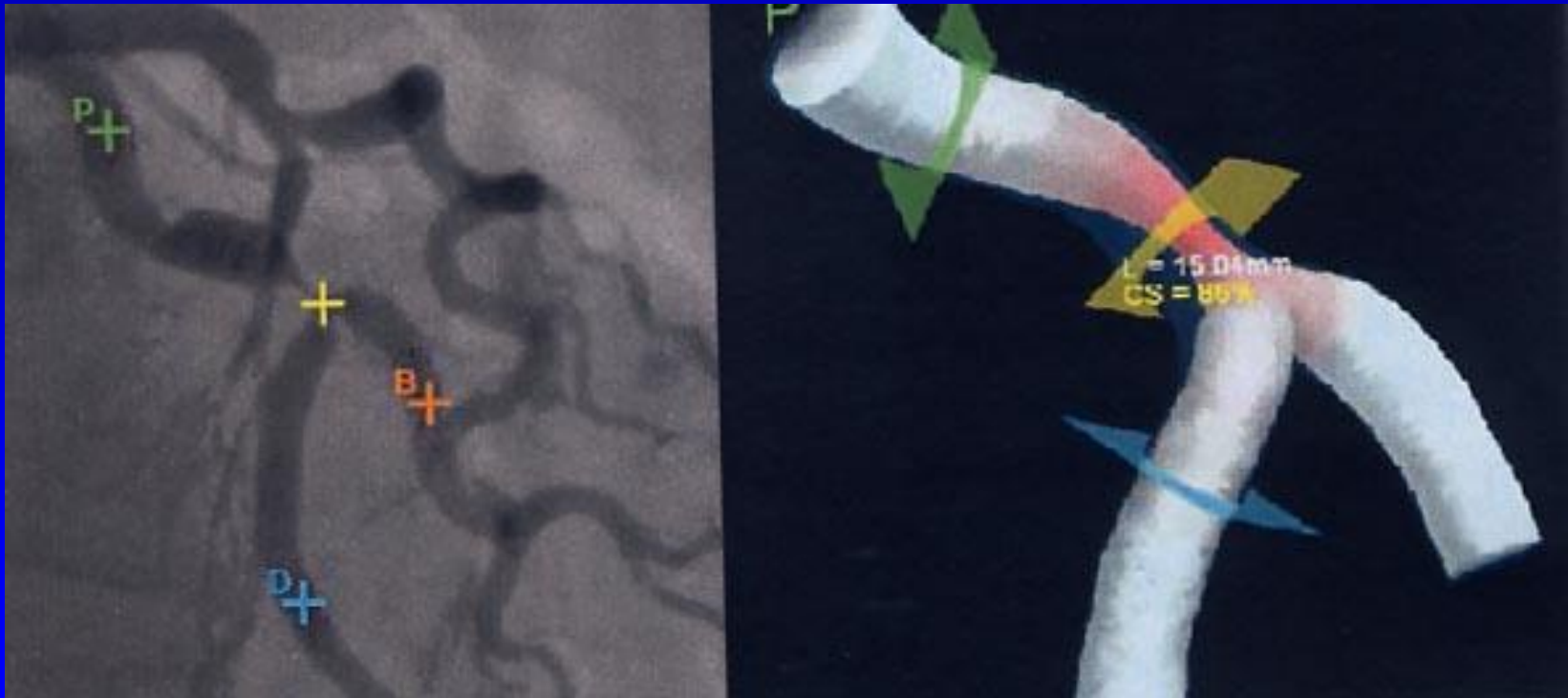
Invazivní metody pro detekci ischemie myokardu



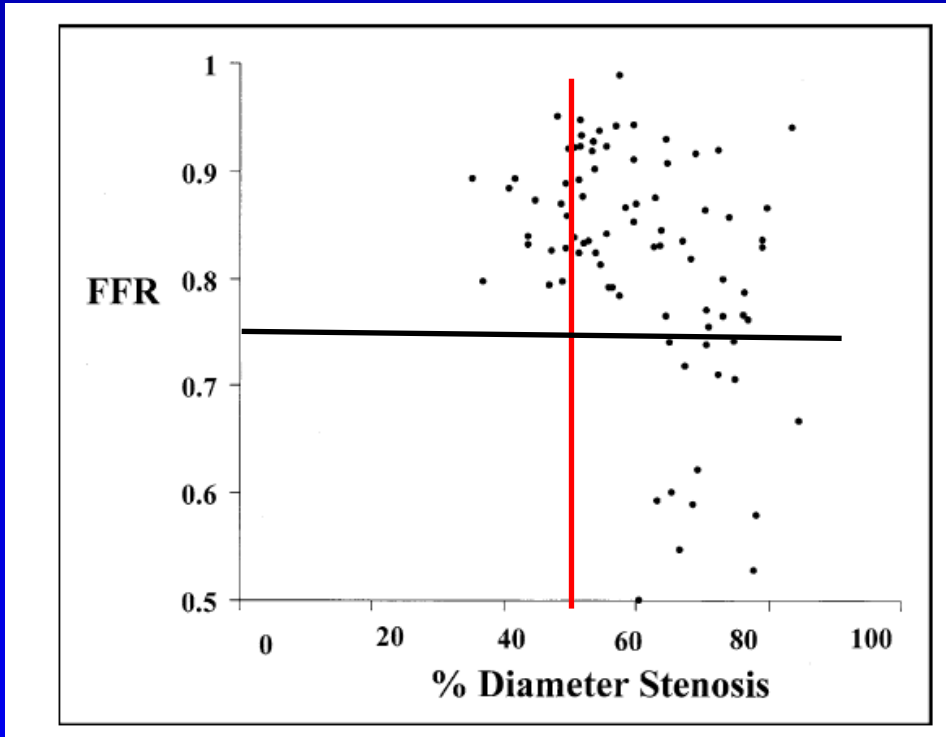
- Angiografie
- Intravaskulární ultrazvuk
- Optická koherentní tomografie
- Frakční průtoková rezerva
- Koronární průtoková rezerva



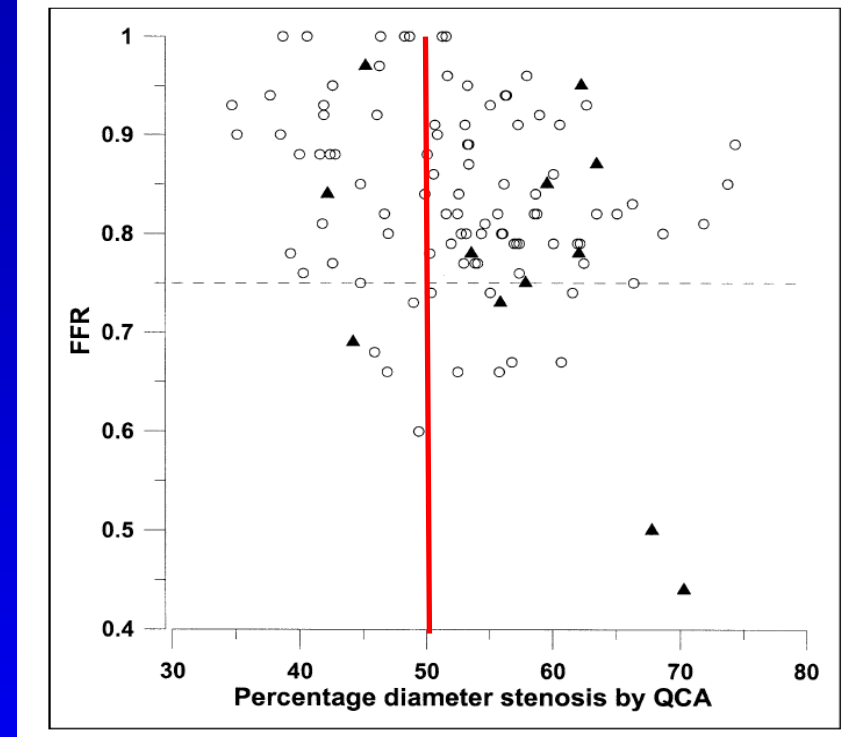
Moderní SKG



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Fisher JJ, Am J Cardiol 2002;90:210-215



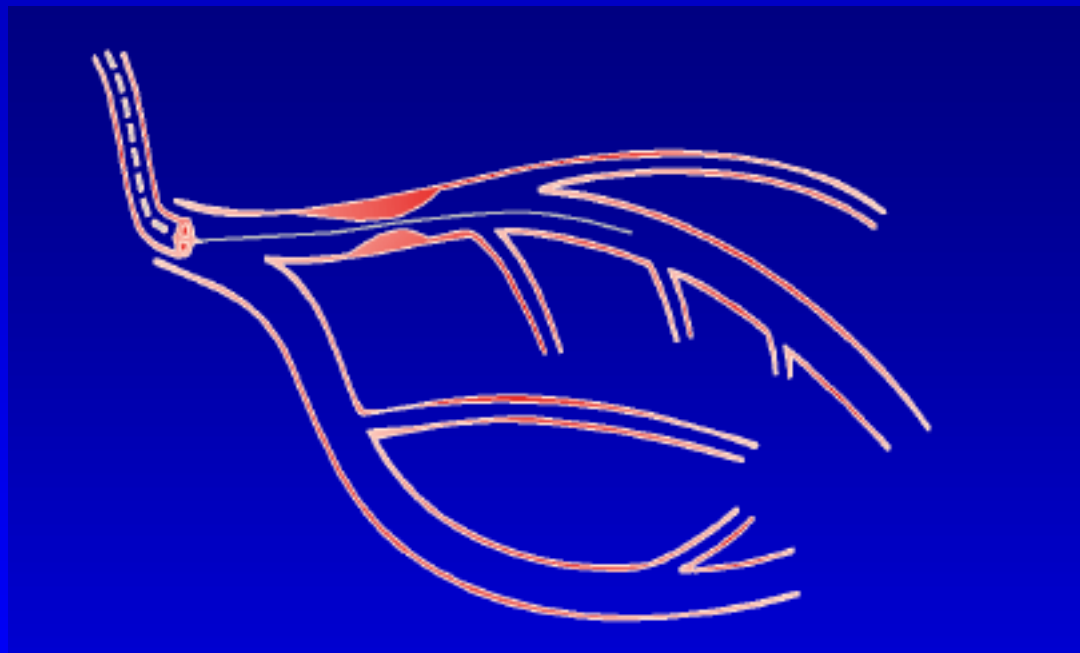
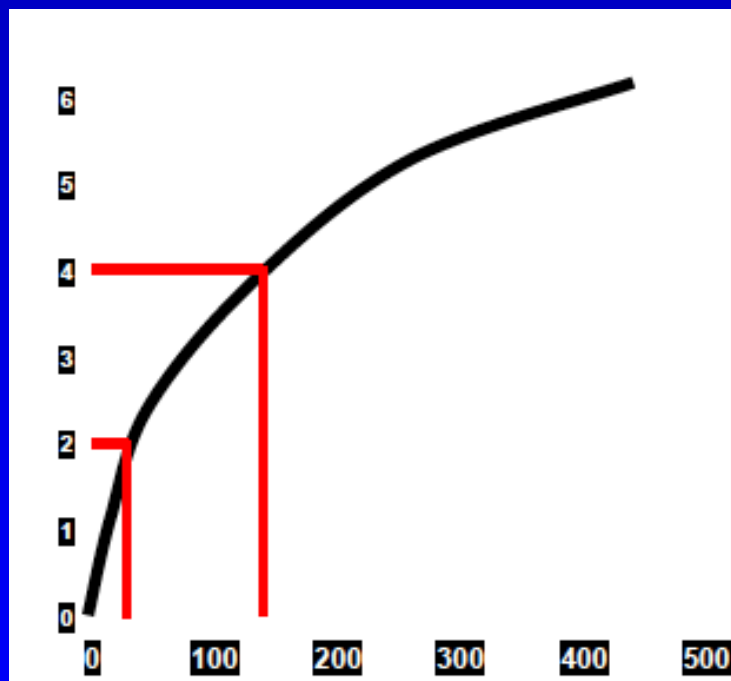
Chamuleau. Am J Cardiol 2002;89:377-380



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Rozsah ischemie je stenózou a velikostí zásobované oblasti

Velikost tepny (mm)



Teritorium myokardu (gramy)



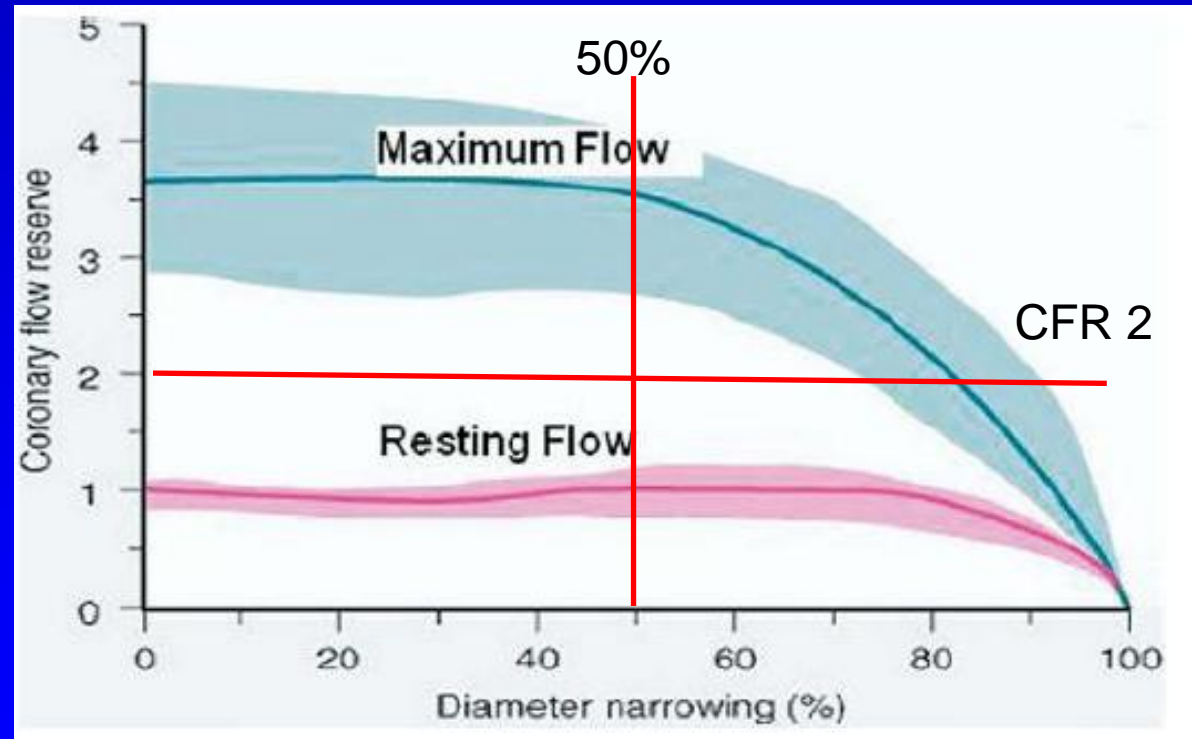
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Seiler C. Circulation 1992, Pijl
N. Nice 2005

EXPERIMENTAL STUDIES

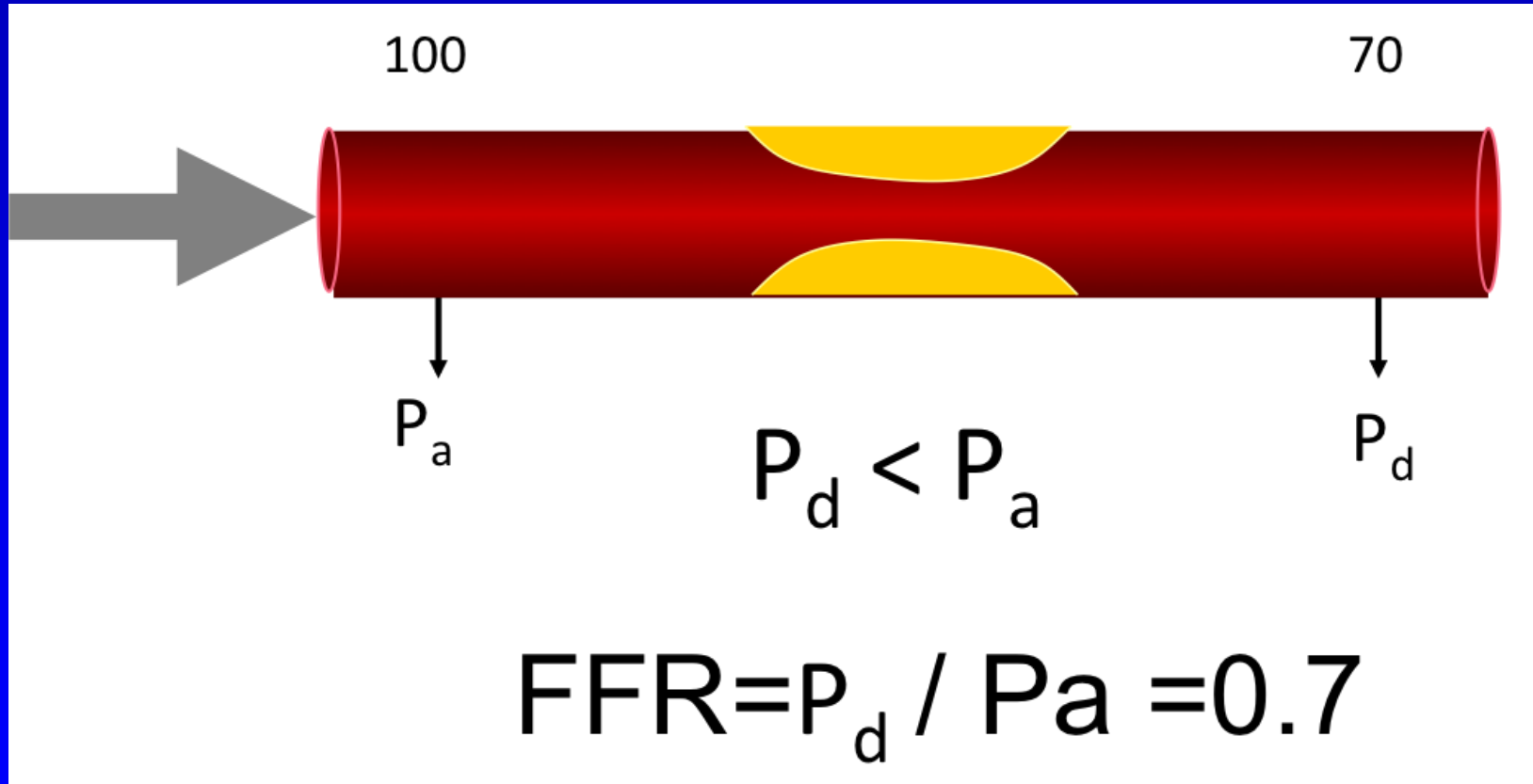
Coronary Flow Reserve as a Physiologic Measure of Stenosis Severity

K. LANCE GOULD, MD, FACC, RICHARD L. KIRKEEIDE, PhD, MARTIN BUCHI, MD
Houston, Texas



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Frakční průtoková rezerva - FFR

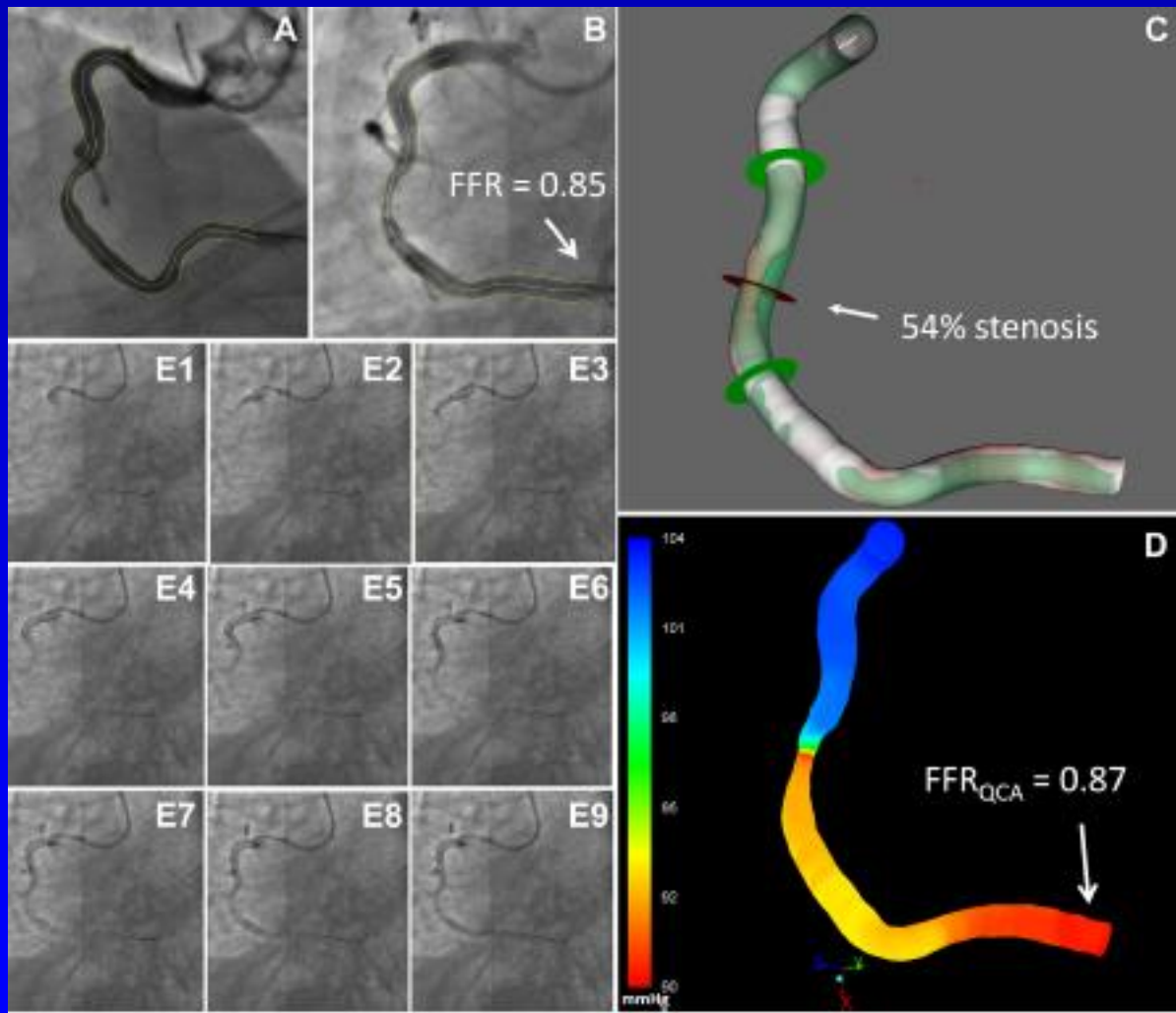


$Q = P/R$,
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pokud je R minimální platí, že $Q \cong P$



FFR na základě QCA a TIMI frame count

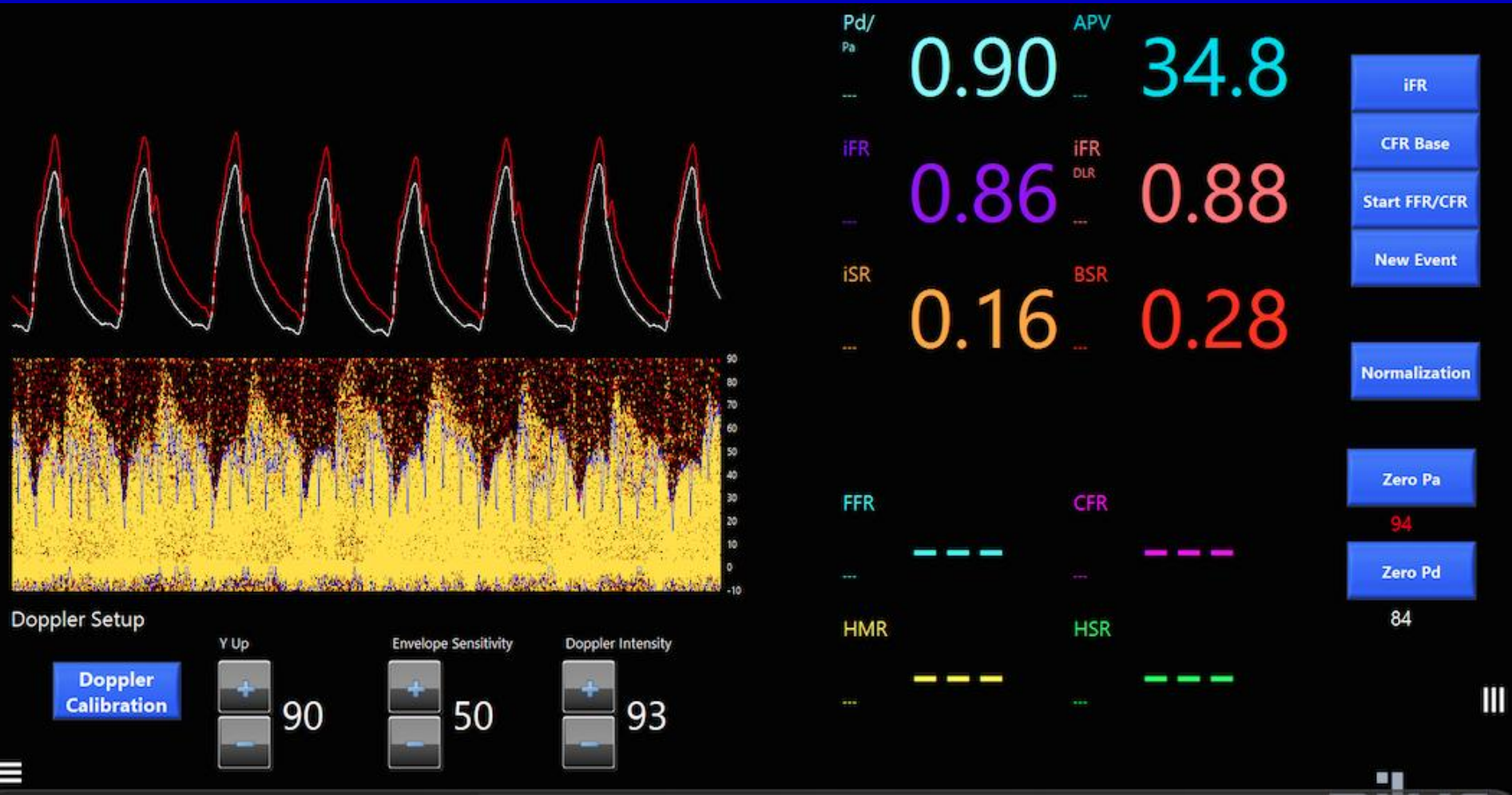


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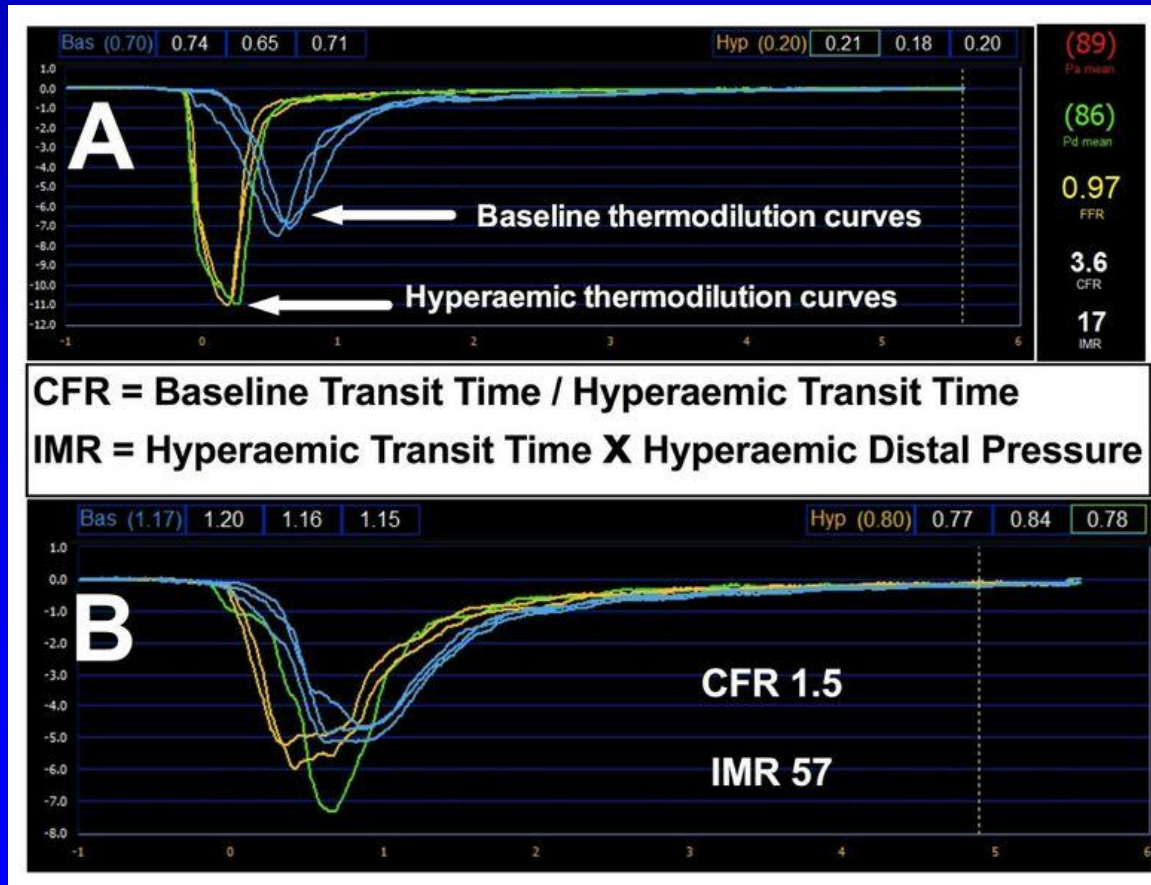
Tu S. JACC CVI 2014;7:768-77

Invazivní hodnocení hemodynamické významnosti stenóz

CFR, FFR (iFR)



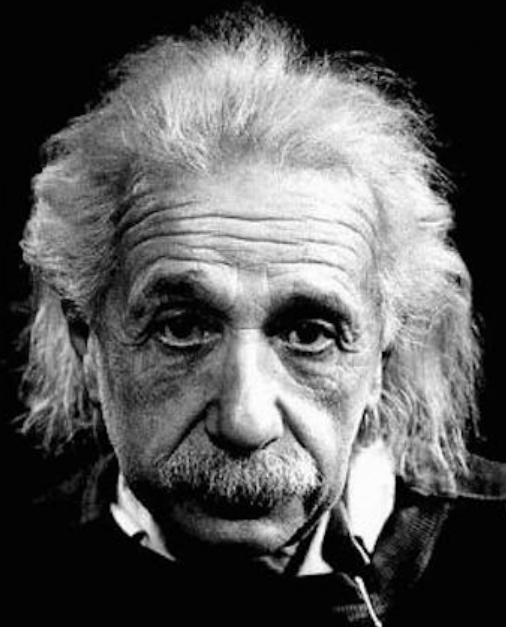
Hodnocení CFR pomocí intrakoronární termodiluce



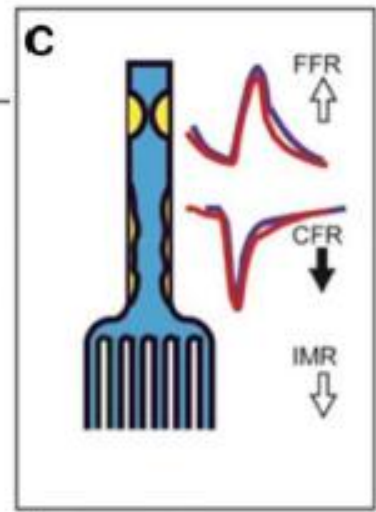
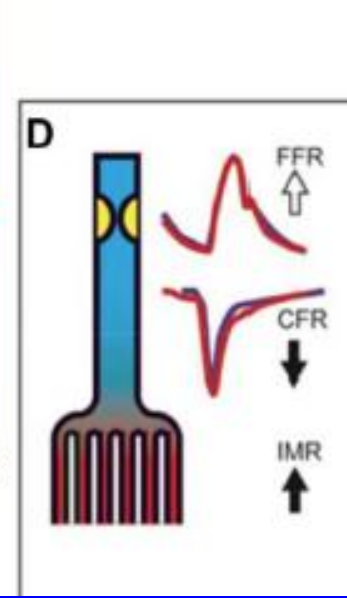
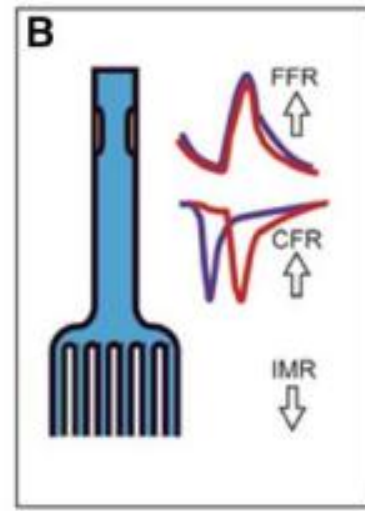
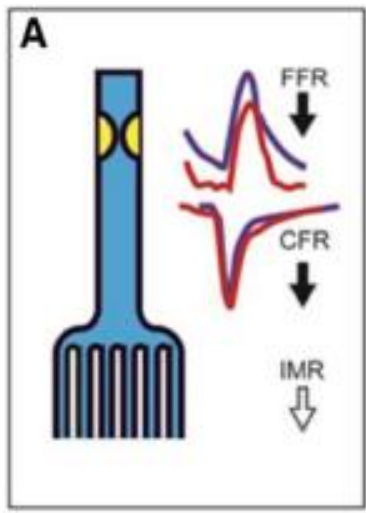
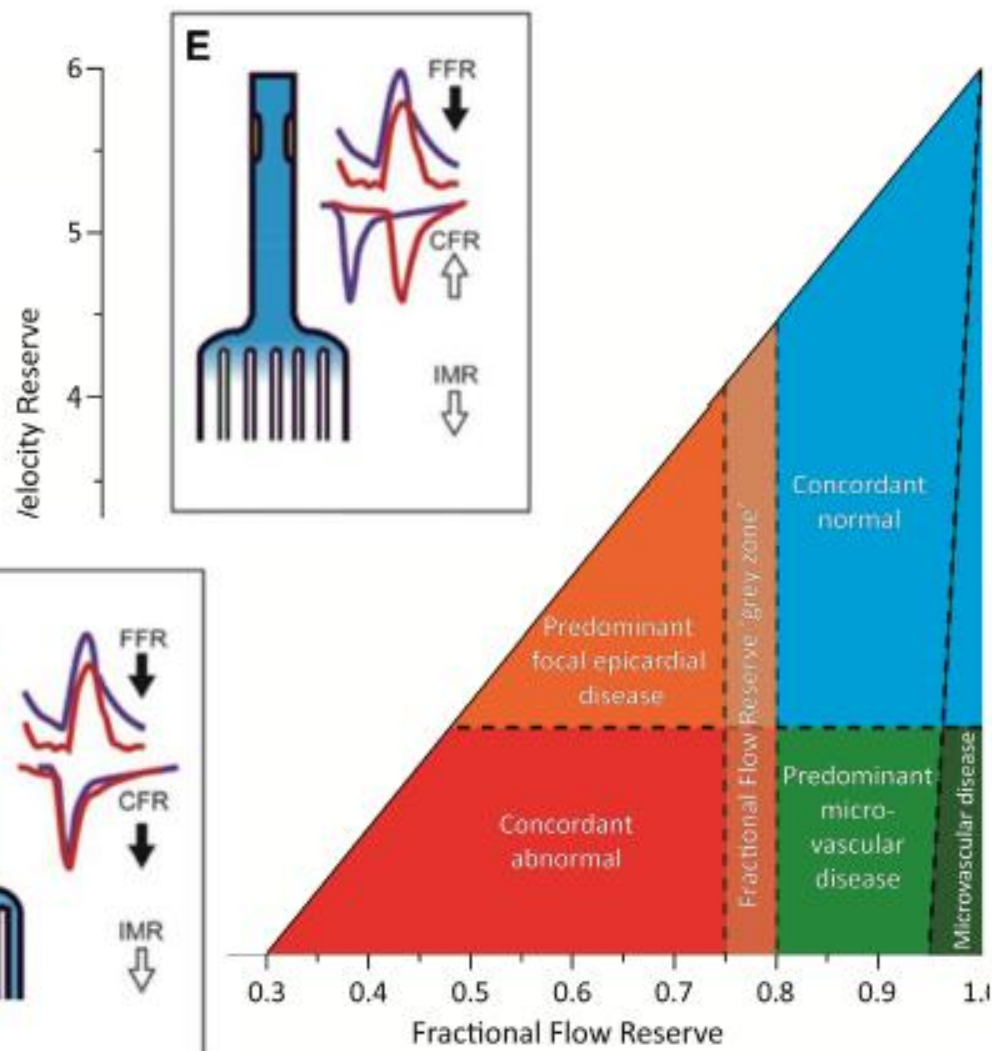
Funkční vyšetření koronárních tepen

“Everything should be made
as simple as possible,
but not simpler.”

Albert Einstein



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Evropská doporučení pro revaskularizaci myoardu

Recommendations for the clinical value of intracoronary diagnostic techniques

Recommendations	Class ^a	Level ^b	Ref. ^c
FFR to identify haemodynamically relevant coronary lesion(s) in stable patients when evidence of ischaemia is not available.	I	A	50,51,713
FFR-guided PCI in patients with multivessel disease.	IIa	B	54
IVUS in selected patients to optimize stent implantation.	IIa	B	702,703,706
IVUS to assess severity and optimize treatment of unprotected left main lesions.	IIa	B	705
IVUS or OCT to assess mechanisms of stent failure.	IIa	C	
OCT in selected patients to optimize stent implantation.	IIb	C	

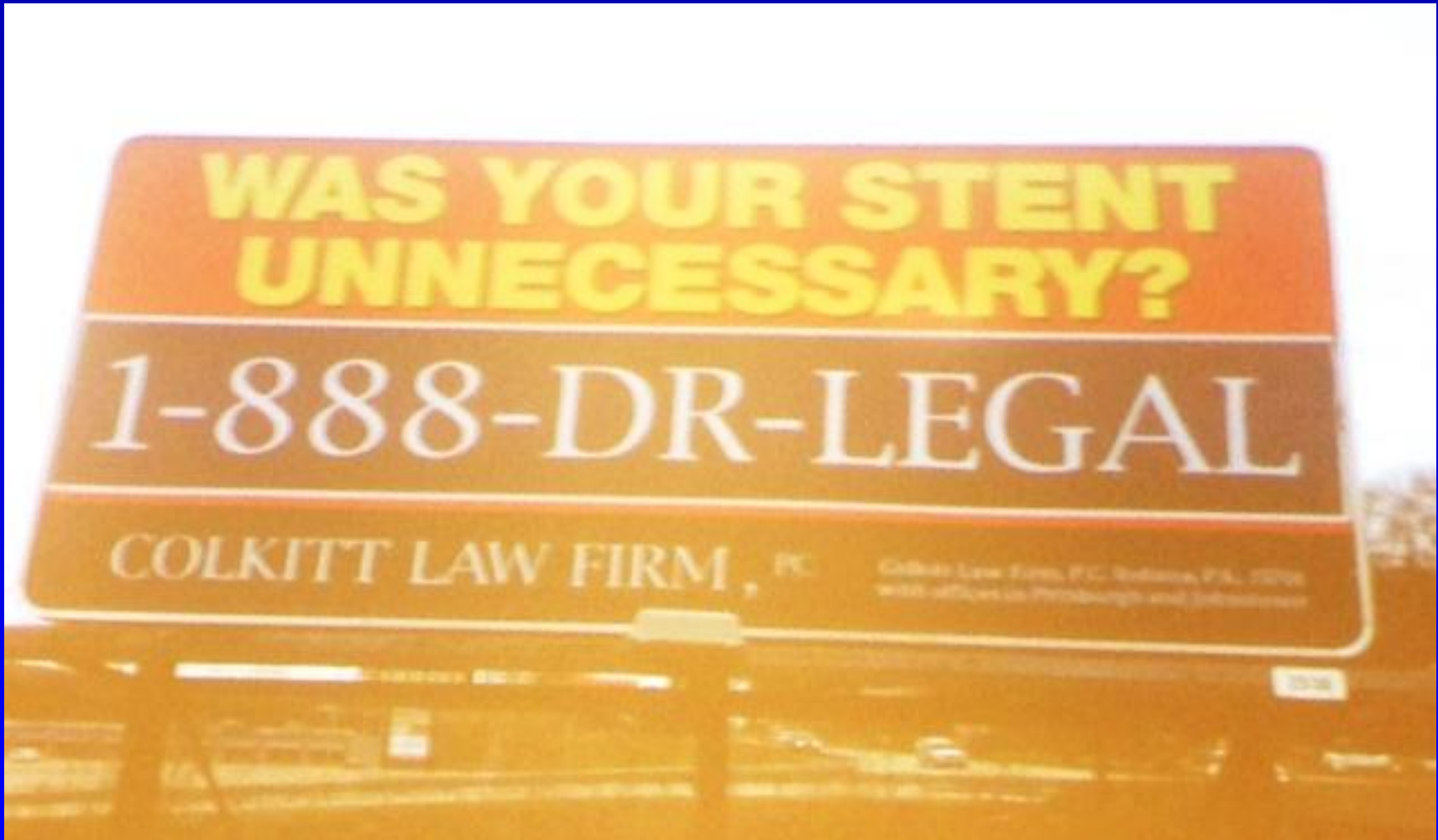


Závěr

- Rozsah ischemie myokardu je v úzkém vztahu k prognóze pacienta
- Indikace koronárních intervencí (perkutánních i chirurgických) musí být veden na základě příkazu ischemie
- Intervence lézí nezpůsobujících ischemii poškozuje pacienta



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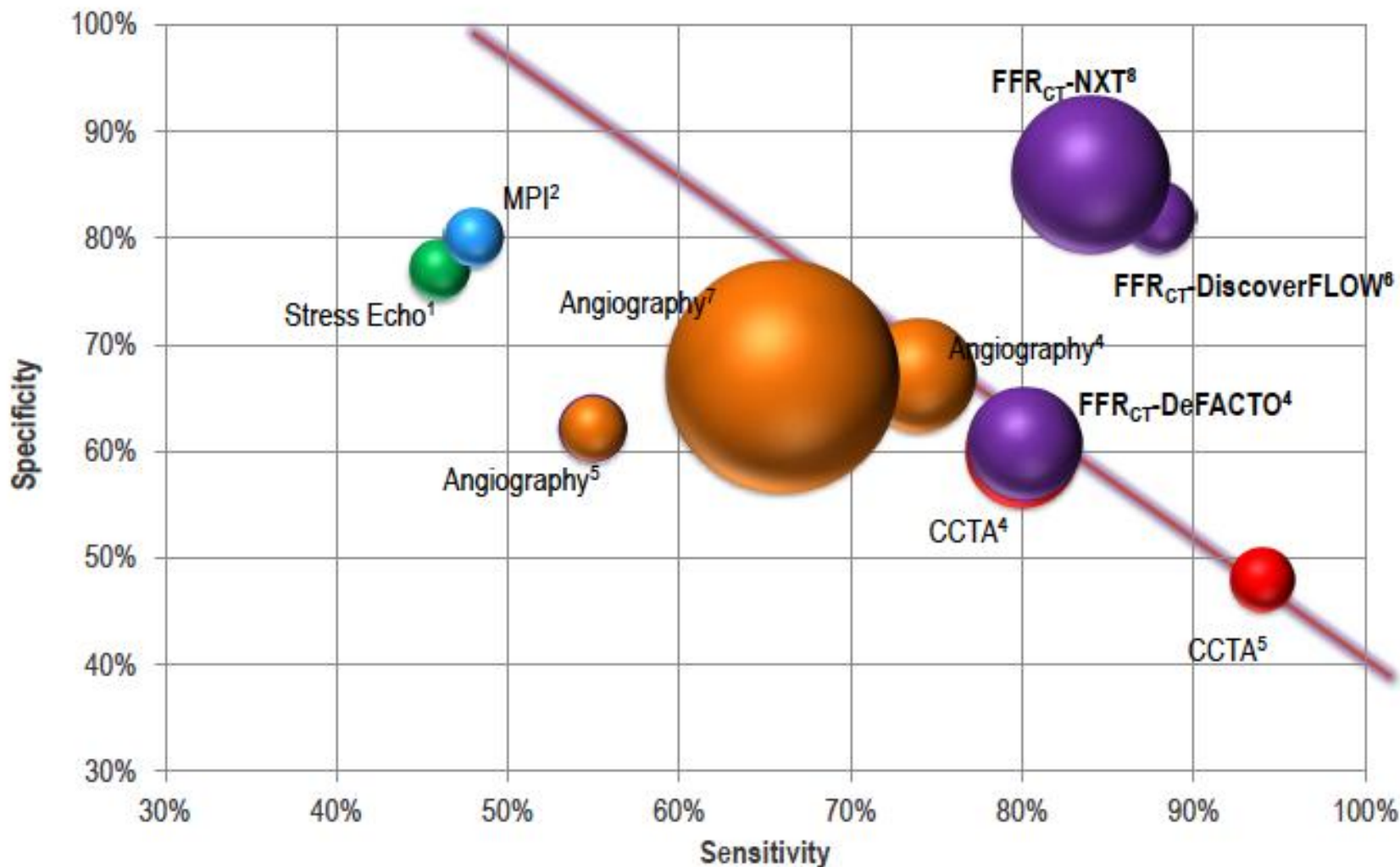


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Non-invasive tests/FFR_{CT}/Angiography vs. FFR



1. Jung et al.

2. Mellkian et al.

3. Muller et al.

4. Min et al.

EHJ 2008;29:2536-2543.

JACC Intervention 2010;3:307-314

JACC Intervention 2011;4

JAMA 2012;308:1237-1245

5. Meijboom et al.

6. Koo et al.

7. Park et al.

8. Norgaard et a.

JACC 2008;52:636-43

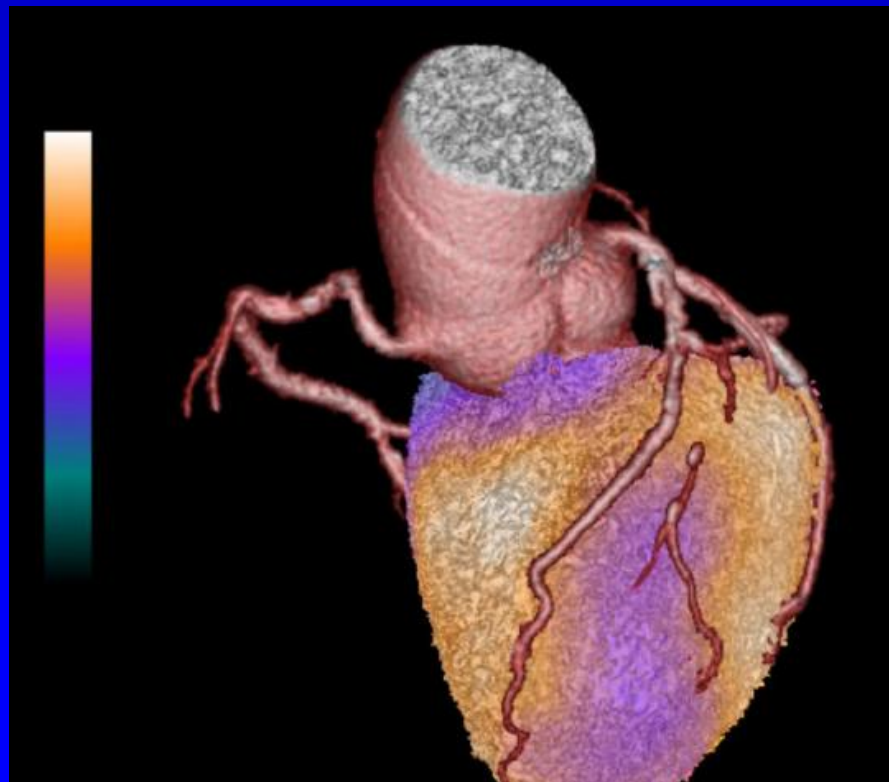
JACC 2011;58:1989-97

JACC 2012

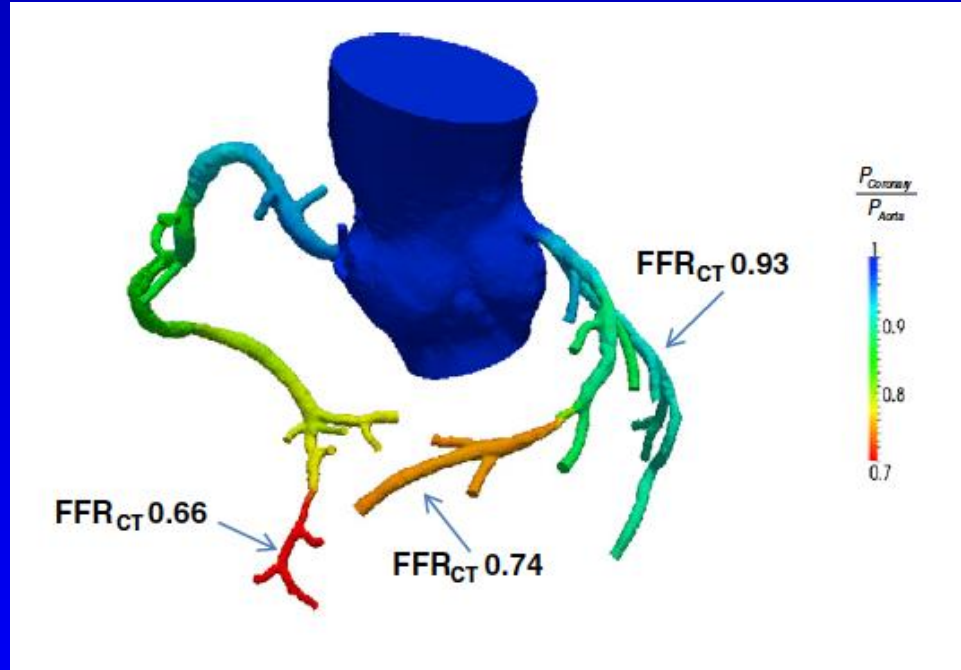
JACC 2014



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Neinvazivní zobrazení koronárních tepen CT angiografie a CT FFR



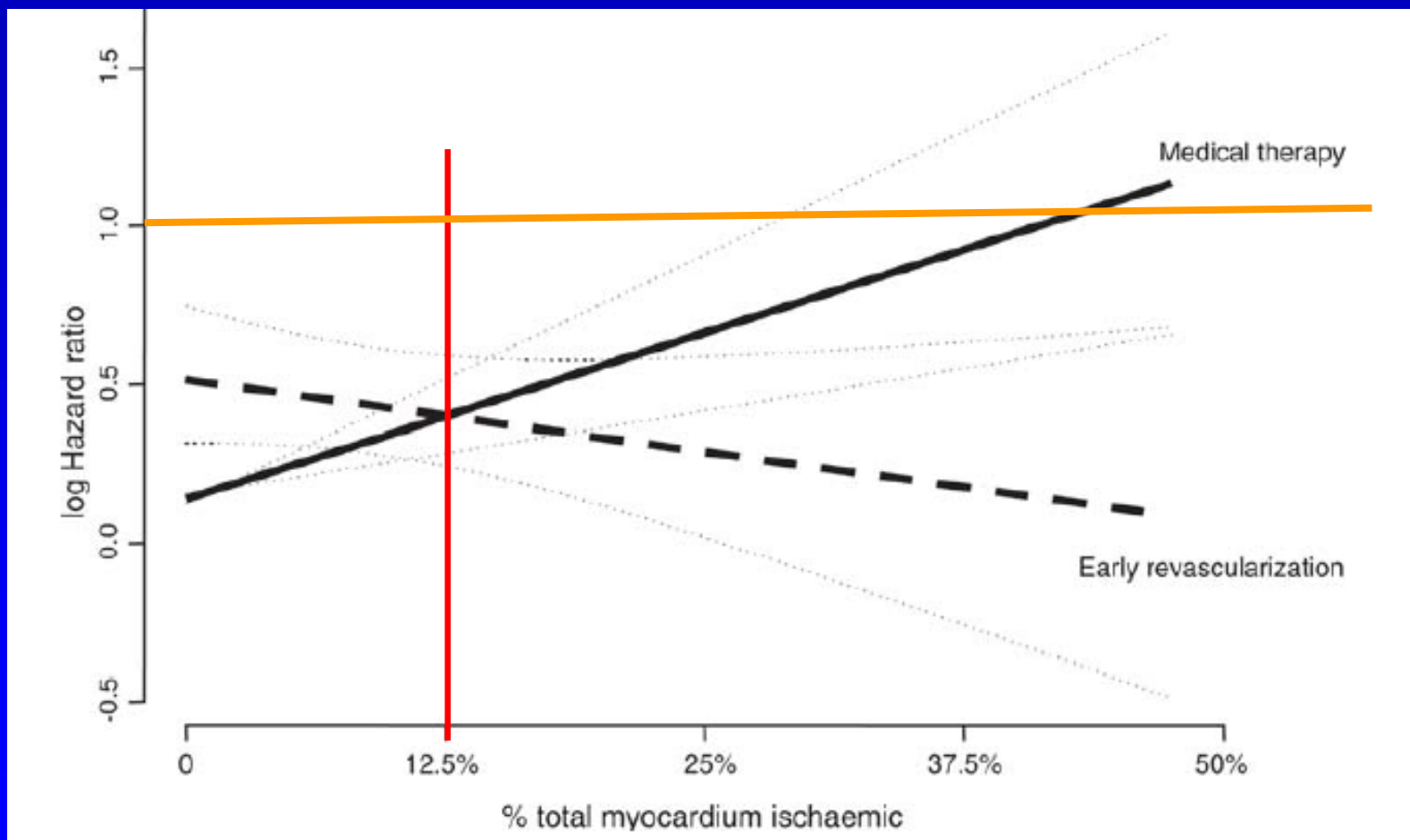
Vliv koronární perfúze vs. angiografického hodnocení stenóz na prognózu

Table 2. Association Between Coronary Flow Reserve, Luminal Angiographic Severity, and Clinical Events

Outcome	Univariable Model Hazard Ratio (95% CI)		Multivariable Model* Hazard Ratio (95% CI)	
	CFR†	CADPI‡	CFR†	CADPI‡
Cardiovascular death or heart failure§	2.17 (1.34–3.52)	1.10 (0.99–1.21)	2.02 (1.20–3.40)	1.17 (1.01–1.34)
All-cause death or heart failure§	1.91 (1.29–2.83)	1.05 (0.97–1.15)	1.64 (1.08–2.48)	1.15 (1.03–1.29)
Cardiovascular death, heart failure,§ or myocardial infarction¶	1.90 (1.23–2.93)	1.13 (1.03–1.24)	1.63 (1.02–2.59)	1.22 (1.08–1.38)



OMT vs. PCI a prognóza pacientů u rozdílného rozsahu ischemického myokardu



Cardiac CT – one stop shop

- CT angiografie
- CT morfologie stenóz
- CT FFR
- CT perfúze



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Coronary Flow Reserve as a Physiologic Measure of Stenosis Severity

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Houston, Texas

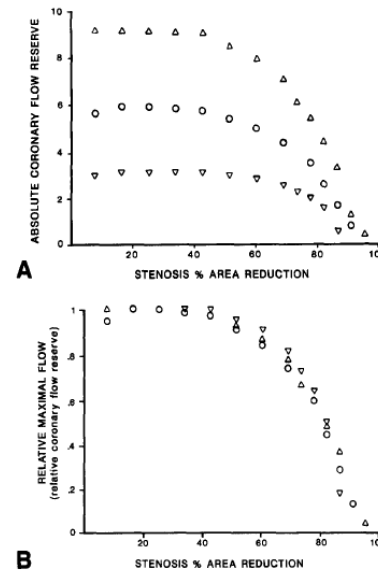


Figure 3. A, Changes in coronary flow reserve during phenylephrine and nitroprusside infusion during progressive coronary artery stenosis in one experiment. Absolute coronary flow reserve is plotted on the vertical axis, defined as maximal flow divided by coronary flow at rest measured by flow meter. Percent area stenosis is plotted on the horizontal axis, measured by the arterial constrictor and confirmed by arteriography, with length and normal diameter remaining constant. Absolute coronary flow reserve showed marked variation for any given fixed stenosis depending on aortic pressure. B, Relative maximal coronary flow or relative flow reserve, defined as maximal flow in the stenotic artery divided (normalized) by normal maximal flow in the absence of the stenosis, showed little variation over a wide range of aortic pressures and heart rates during phenylephrine; inverted

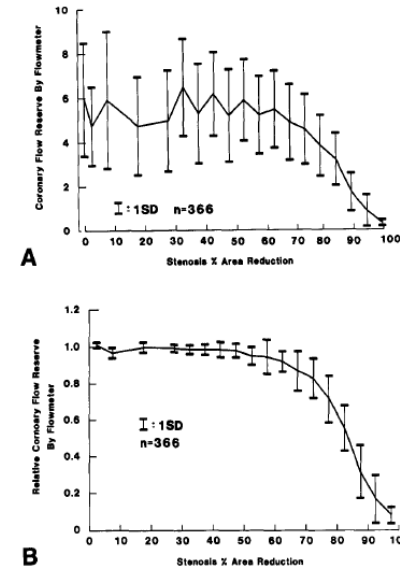


Figure 4. A, Absolute coronary flow reserve (maximal flow divided by flow at rest) for all 366 experiments over the full range of changes in aortic pressure and stenosis severity. B, Relative maximal coronary flow or relative flow reserve (maximal flow in stenotic artery divided by normal maximal flow in absence of stenosis) for all 366 experiments over the range of changes in aortic pressure with progressive coronary artery stenosis.

depending on aortic pressure and heart rate. However, relative maximal flow or relative flow reserve was independent of aortic pressure and heart rate (Figure 3B). Relative flow reserve was approximately 0.90 for the 65% stenosis condition. For all stenoses with 65% area narrowing, absolute



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