

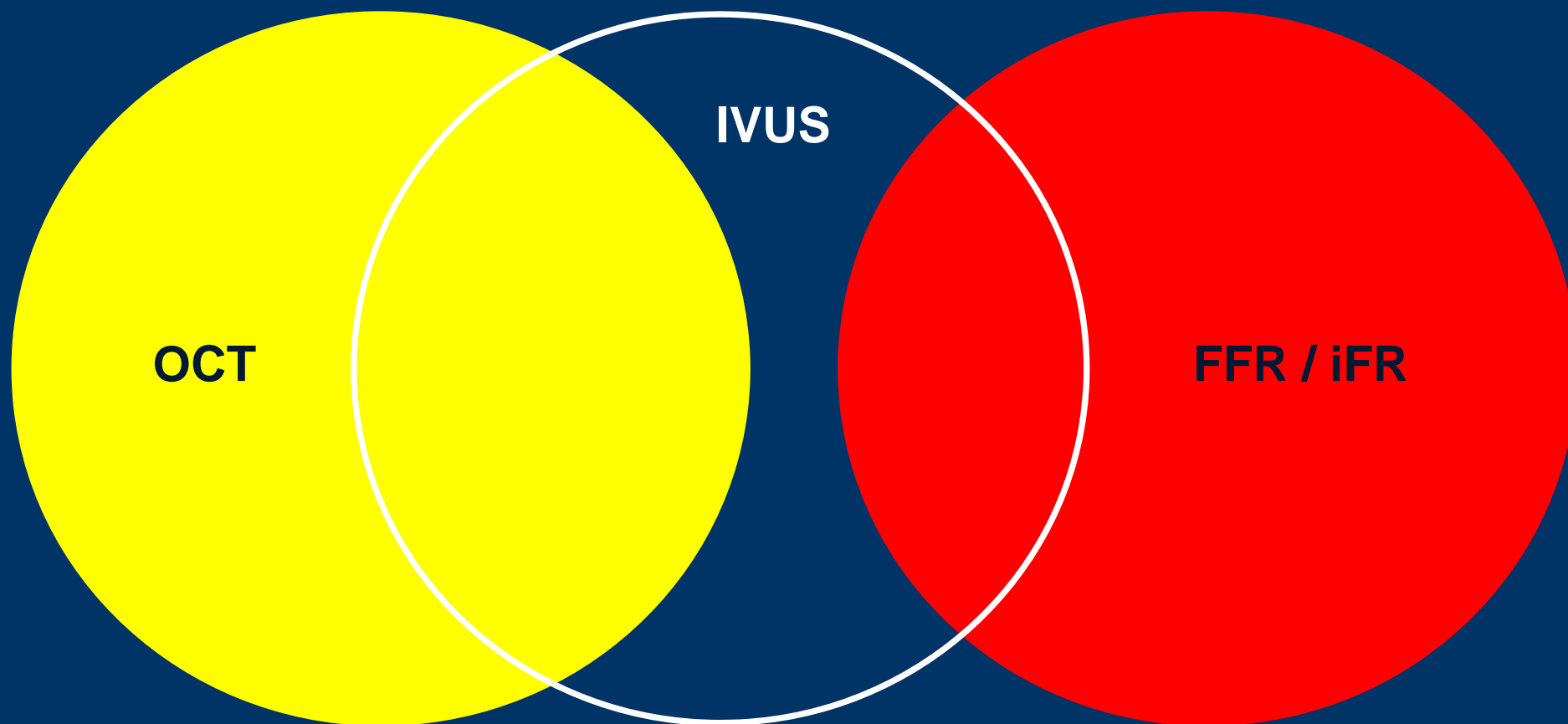


Intravaskulární ultrazvuk a virtuální histologie



MUDr. Tomáš Kovárník, PhD.
II. Interní klinika VFN a 1. LF UK

Postavení IVUS



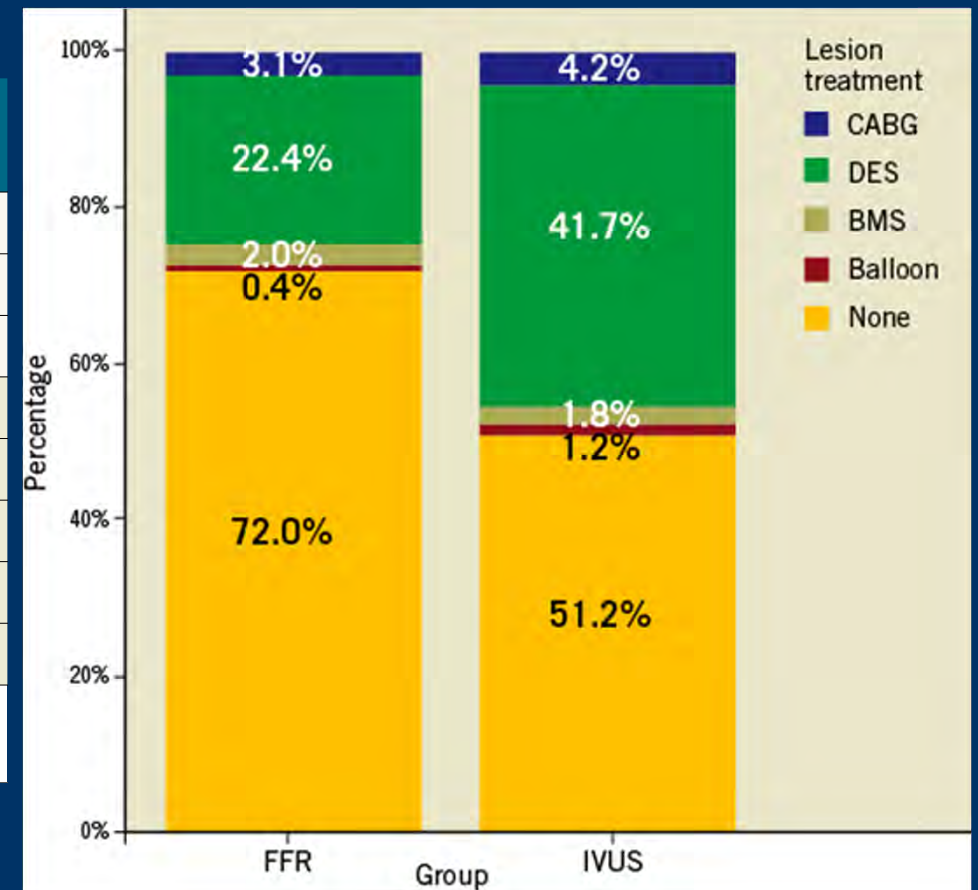
MLA hemodynamická významnost

	Abizaid AJC 1998; 82: 423-8	Nishioka JACC 1999; 33: 1870-8	Takagi, Circ. 1999; 100: 250-5	Briguori AJC 2001; 87: 136-41	Takayama CCI 2001;53:48- 55	Lee AJC 2010; 105: 1378-84	Kang Circ CV Interv 2011; 4:65-71 (AJC, 2012;109: 947-53)	Ahn JACC CV Interv 2011;4:665- 71	Ben-Dor Eurointervent 2011;7:225-33 (Cardiovasc Revasc Med 2012;13:177-82)	Yang CCI 2013	Koo JACC CV Interv 2011;4:80 3-11	Waksman JACC 2013;61:9 17-23	Gonzalo JACC 2012;59:1 080-9	Stone TCT2012 (VERDICT - FIRST)	Chen Int J Cardiol 2012; in press	Kwan Chin Med J 2012;125:42 49-53
	CFR	SPECT	FFR	FFR	FFR	FFR	FFR	SPECT	FFR	FFR	FFR	FFR	FFR	FFR	FFR	FFR
N	112	70	51	53	14	94	236	170	205	206 LAD	267	367	47	544	323	169 LAD
% abnormal	40%	65%	49%	23%	50%	40%	21%	26%	26%	44%	33%	28%	46%	31%	54%	59%
IVUS																
Ref lumen (mm ²)	8.3 7.4	11.9 10.6	9.3	7.8	10.3	5.5 5.9	7.6		8.6		7.8 6.7		7.0			
MLA (mm ²)	4.4	4.3	3.9	3.9	3.5	2.3	2.6	2.1	3.5	3.1	3.0	3.5	2.6	3.3	2.9	3.0
MLA Cut-off (mm²)	4.0	4.0	3.0	4.0	<i>n/a</i>	2.0	2.4	2.1	3.2	3.2 2.5	2.8	3.1	2.4	2.9	3.0	3.0
C- statistic							0.80	0.69	0.73	0.78	0.81	0.65	0.63	0.66	0.77	0.86
NPV							96%	91%					65%	81%	76%	82%
PPV							37%	39%			47%		67%	47%	73%	84%
<i>Other determina nts of ischemia</i>	LL				MLA/ LL	PB LL	PB LAD	PB	RVD	Prox -Mid LL PB	Prox -Mid LAD	RVD PB		LAD EEM	PB LL LAD	PB LL
QCA																
Length (mm)			14	8.5	17.9	15.1		21.2	11.4	22.7	16.5	15.0	7.1	13.9	18.4	20.6
Ref (mm)			3.0	3.1	2.9	2.7		3.3	3.3	3.3	3.1	2.9	2.6	2.9	3.1	3.4
DS (%)			46	52	53			55	48	54	50	45	51	48	64	65

Srovnání IVUS vs. FFR indikace k PCI

		IVUS (n=488)	FFR (n=463)	p-value
Target vessel	Left anterior descending artery	280 (57.4)	265 (57.2)	0.9
	Circumflex artery	79 (16.2)	88 (19)	0.3
	Right coronary artery	129 (26.4)	110 (23.8)	0.4
Target lesion	Reference vessel diameter, mm	3.05±0.4	3±0.5	0.08
	Stenosis, %	50.5±10	49.5±9	0.1
	Length, mm	13.5±10	14±9	0.4
	FFR	na	0.82±0.09	
	MLA, mm ²	4.22±1	na	1

FFR: fractional flow reserve; IVUS: intravascular ultrasound; MLA: minimum lumen area; PCI: percutaneous coronary intervention



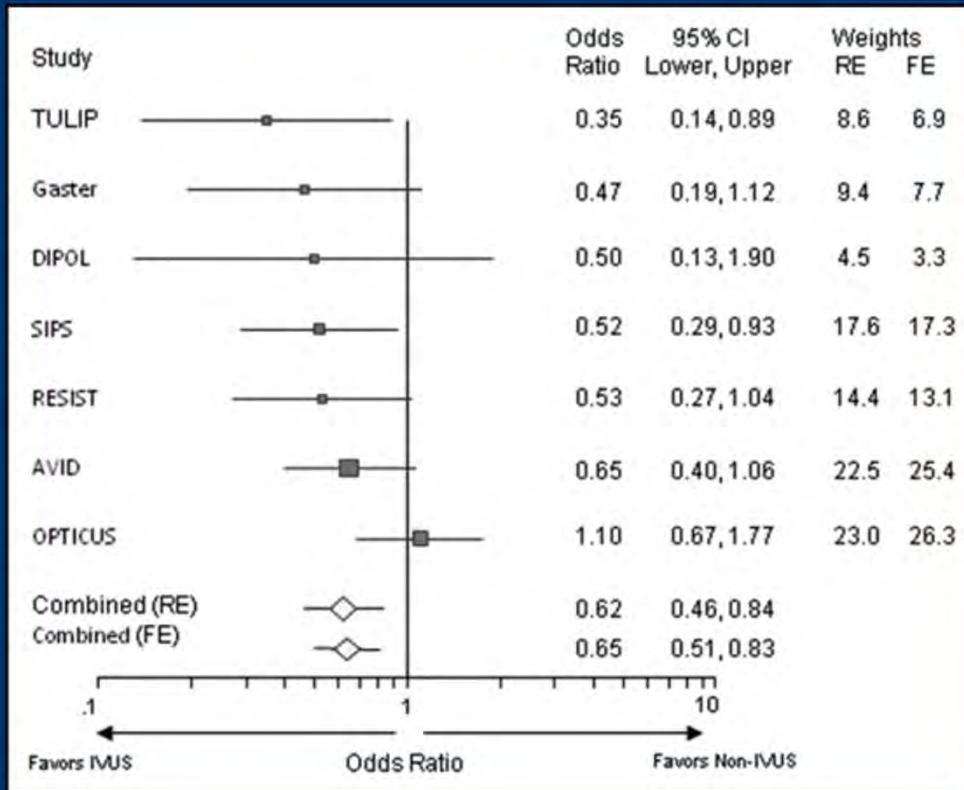
Srovnání IVUS vs. FFR indikace k PCI

Table 3. Clinical events at 2-year follow-up.

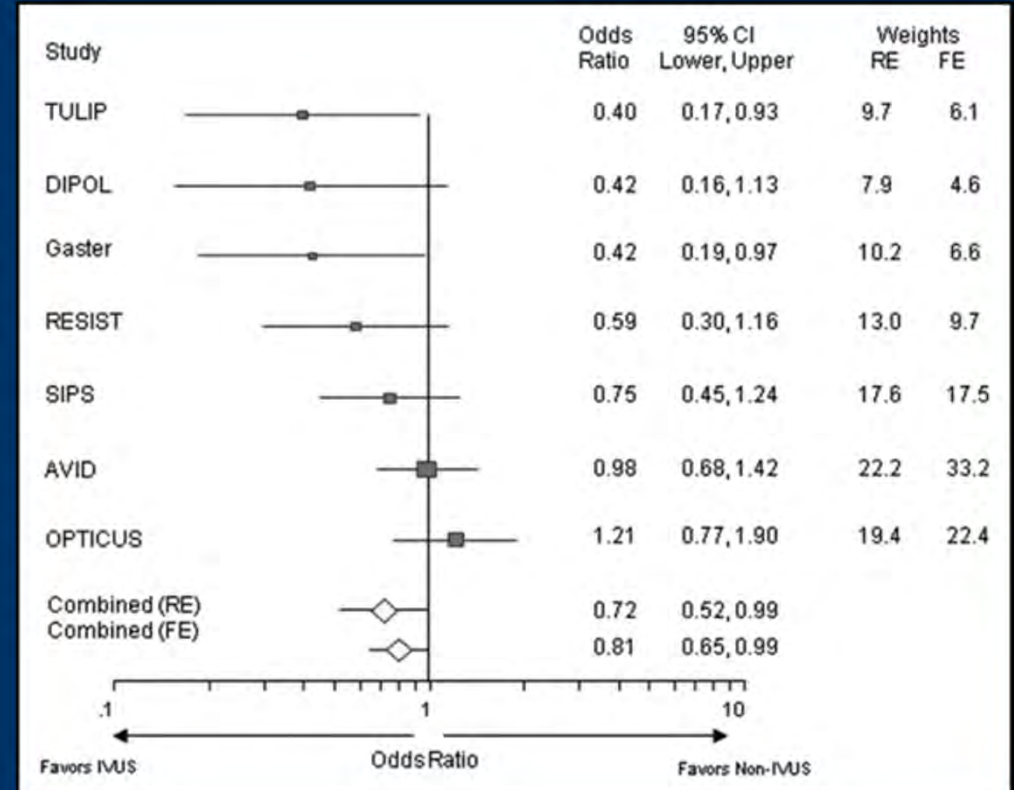
Global	IVUS (n=400)	FFR (n=400)	<i>p</i> -value
Cardiac death	8 (2)	11 (2.75)	0.5
Target lesion MI	1 (0.25)	1 (0.25)	0.9
TLR	9 (2.25)	7 (1.75)	0.7
Deferred	(n=205)	(n=288)	<i>p</i> -value
Cardiac death	5 (2.4)	7 (2.4)	0.9
Target lesion MI	0	0	1
TLR	6 (2.9)	5 (1.7)	0.4

FFR: fractional flow reserve; IVUS: intravascular ultrasound;
MI: myocardial infarction; TLR: target lesion revascularisation

IVUS vedená implantace BMS 2 193 pacientů



TVR: $p < 0,001$



MACE: $p = 0,044$

IVUS vedená implantace DES 19 619 pacientů

IVUS vedení implantací DES snižuje:

-Úmrtí (HR 0.59, $p < 0.001$)

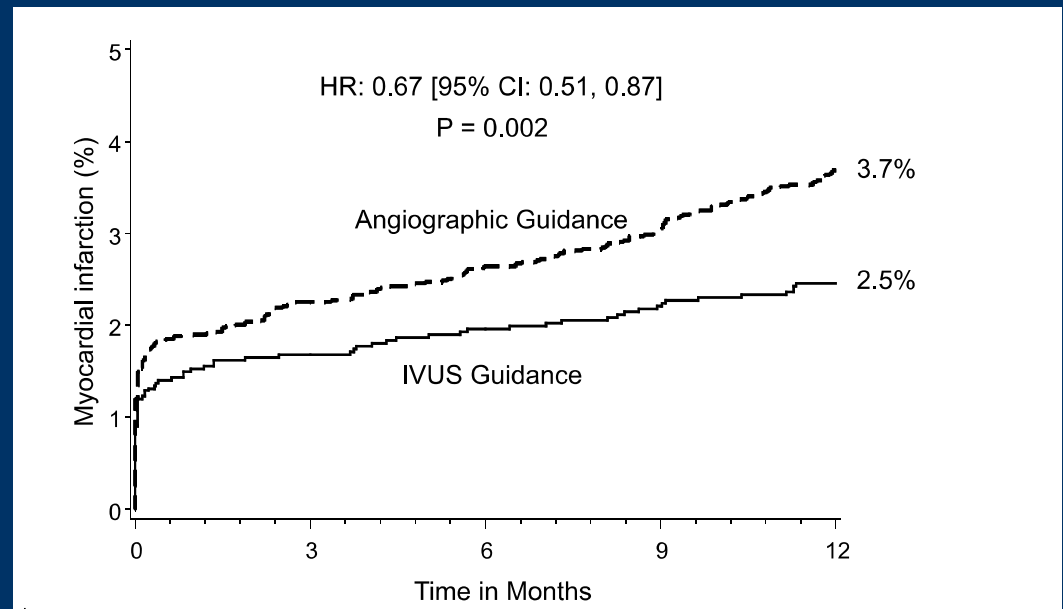
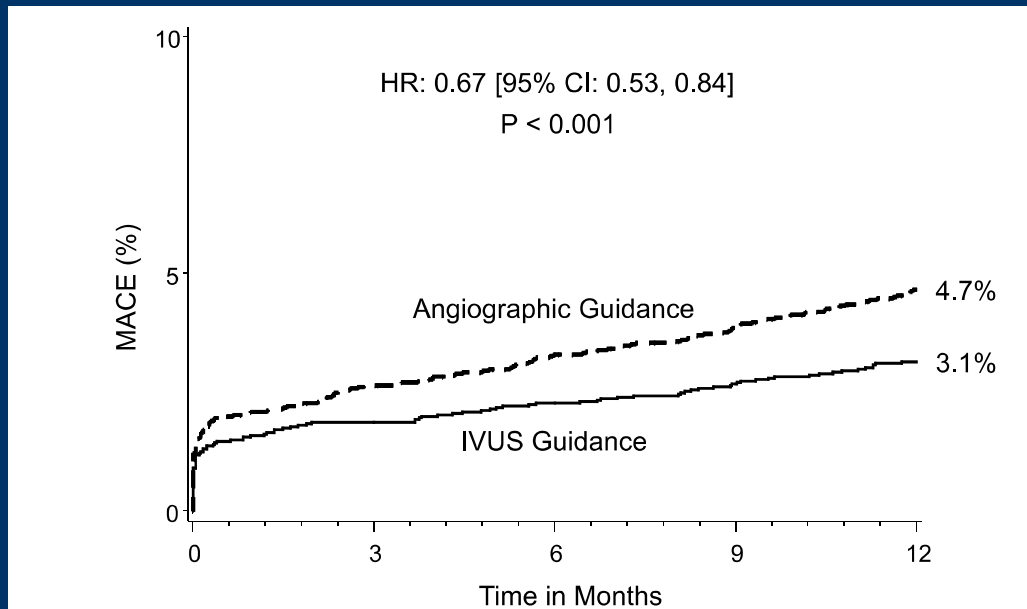
-IST (HR 0.58, $p < 0.0001$)

-MACE (HR 0.87, $p = 0.008$)



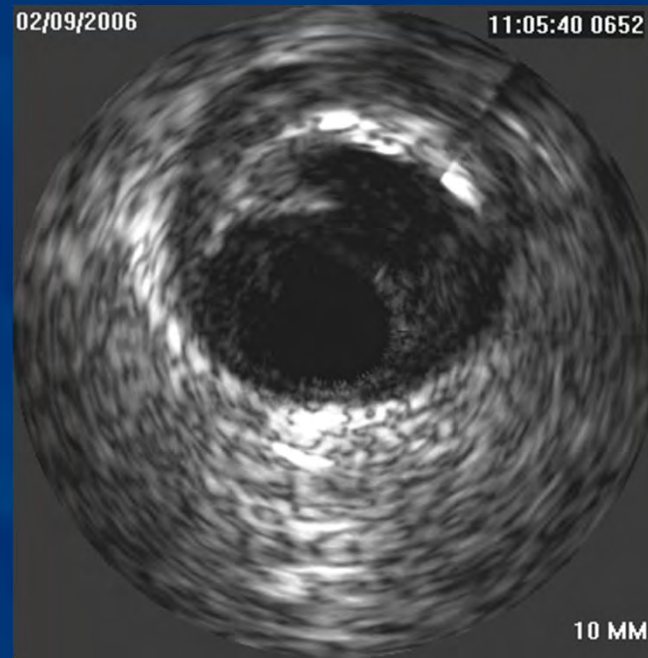
ADAPT-DES

8 575 pacientů



Reálné využití IVUS v kombinaci s OCT a FFR

- Hodnocení a intervence kmene ACS
- Ostiální léze
- CTO intervence
- Vývoj aterosklerózy
- Nové metody vycházející z intravaskulárního ultrazvuku



Studie LITRO study: indikace revaskularizace u stenóz kmene na základě IVUS vyšetření

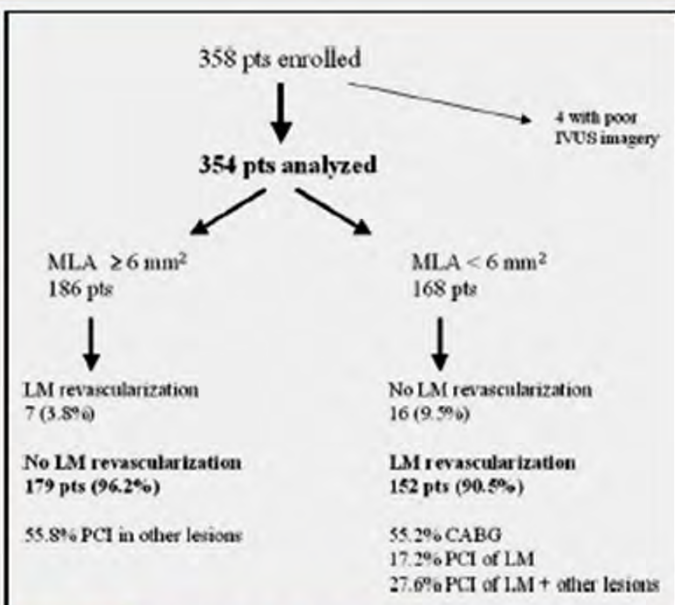


Figure 1 Flow Chart of the Study

CABG = coronary artery bypass graft; IVUS = intravascular ultrasound; LM = left main; MLA = minimum lumen area; PCI = percutaneous coronary intervention; pts = patients.

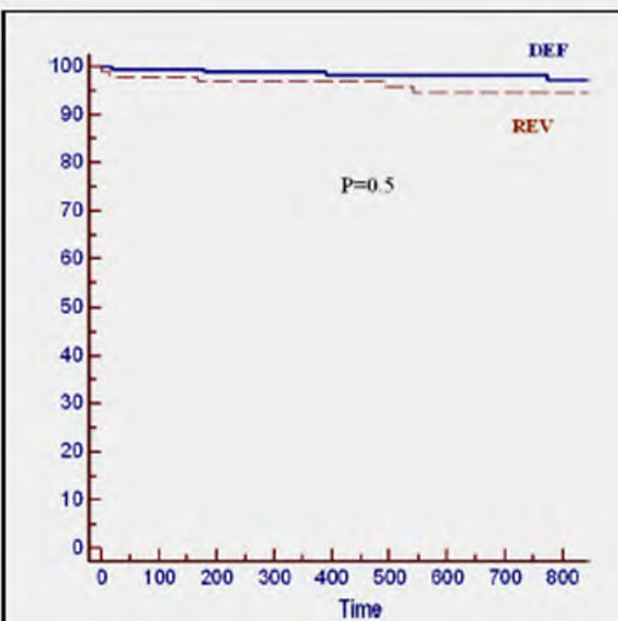


Figure 4 Survival Free of Cardiac Death in Both Groups

Survival free of cardiac death in the deferred (DEF) and revascularized (REV) groups.

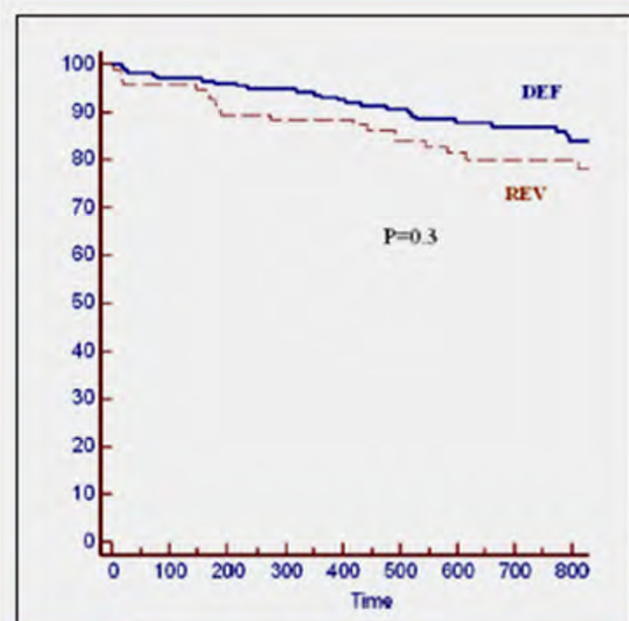
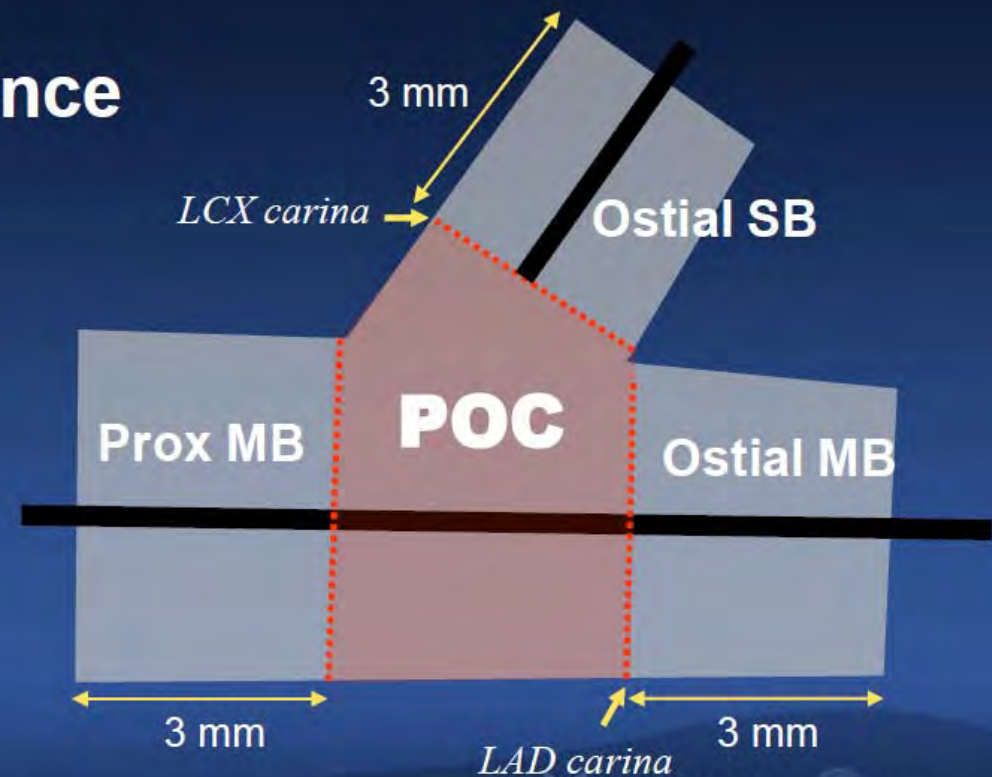


Figure 5 Survival Free of Cardiac Death, Myocardial Infarction, and Any Revascularization in Both Groups

Survival free of cardiac death, myocardial infarction, and any revascularization in the DEF and REV groups. Abbreviations as in Figure 4.

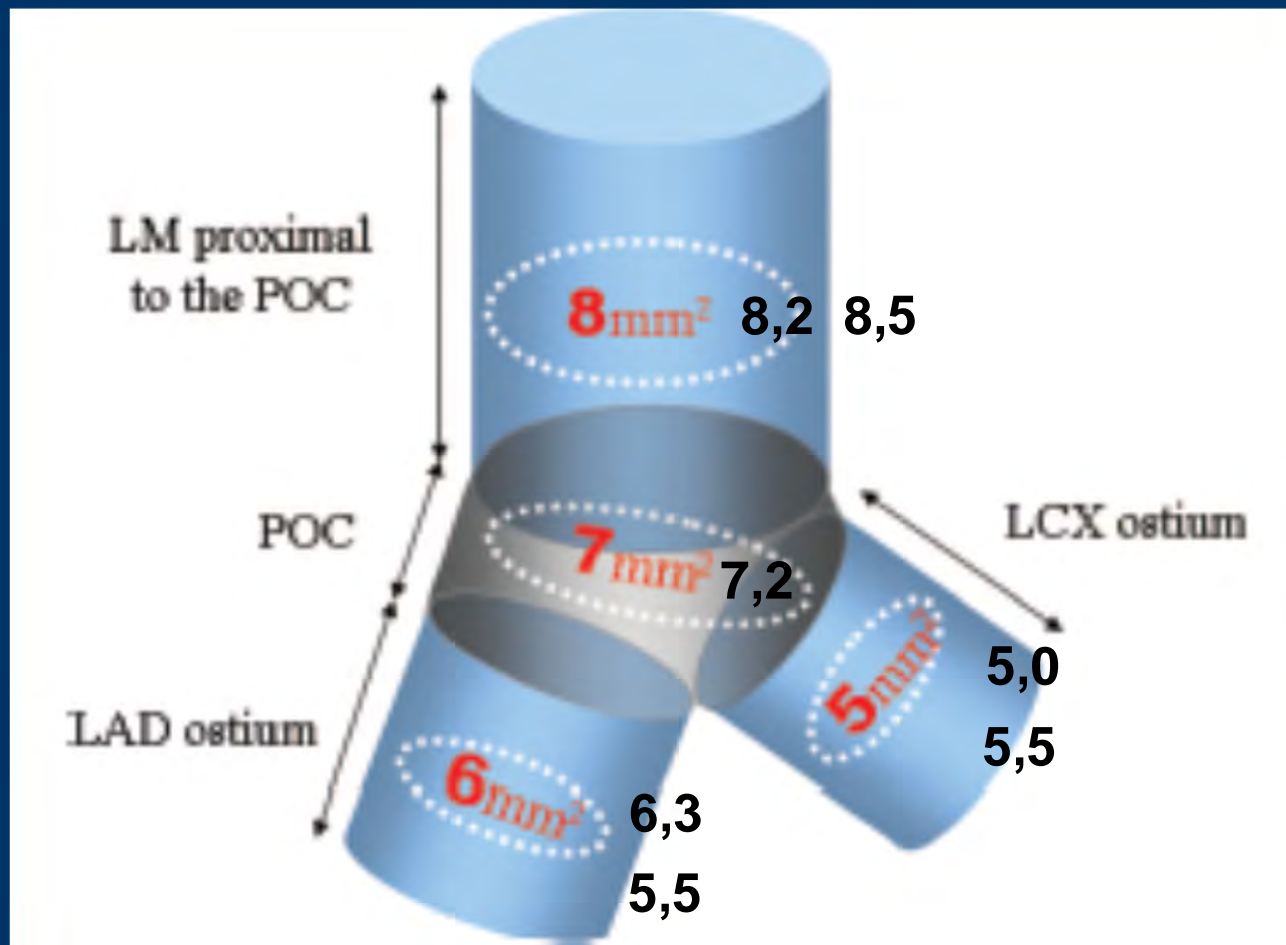
Four Segments of IVUS Measurement

- MB Ostium
- SB Ostium
- Polygon of Confluence
- Proximal MB



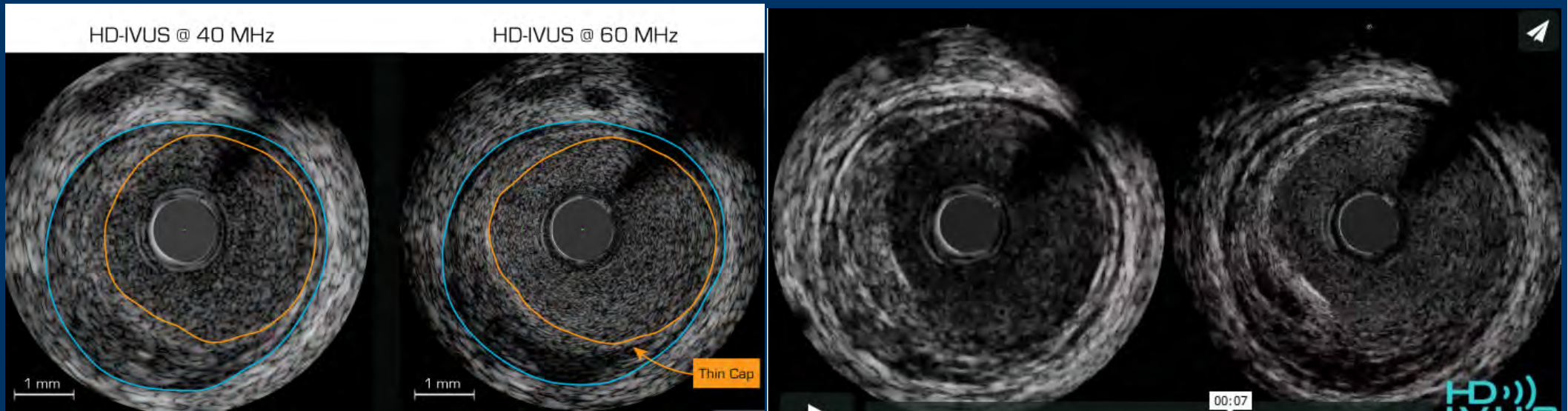
Kang SJ. Am J Cardiol 2011

Cílové hodnoty pro MSA při PCI kmene



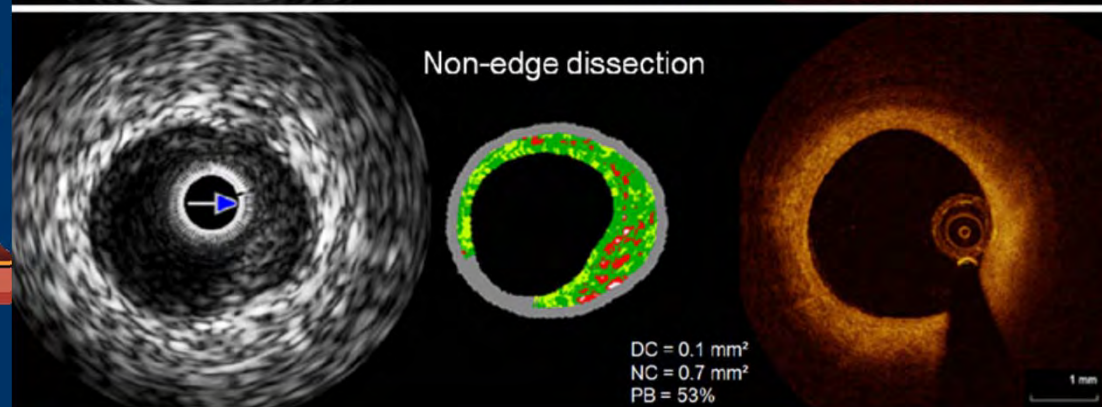
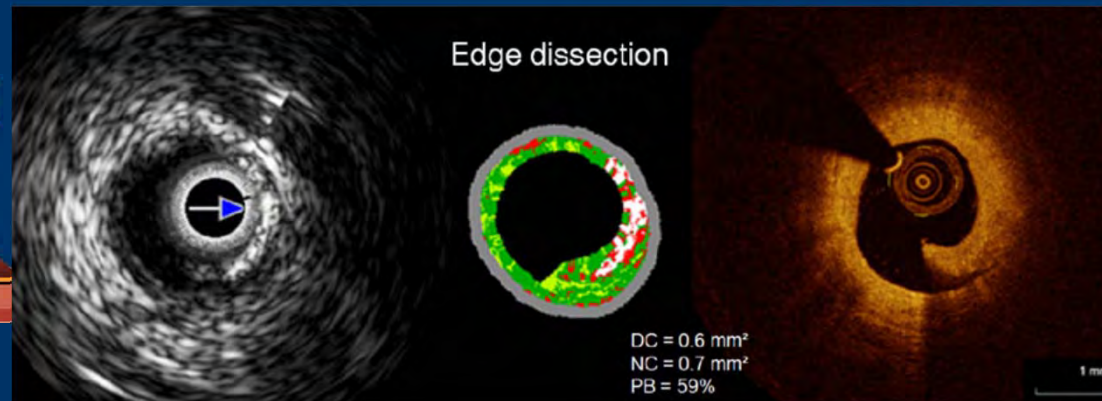
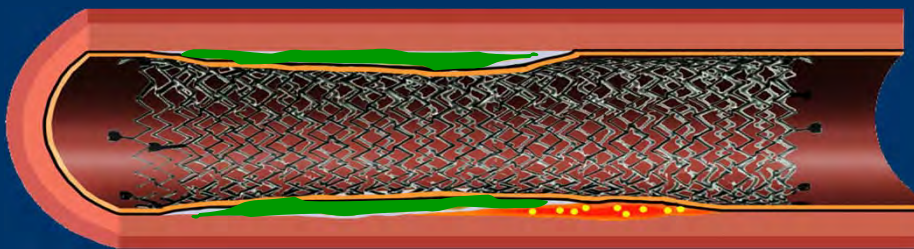
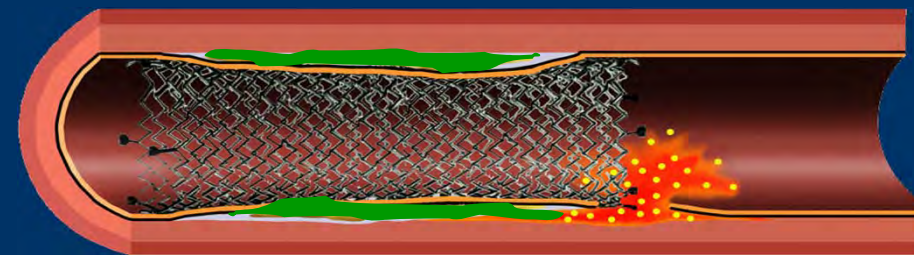
60 MHz IVUS

	60 MHz IVUS	OCT
Axial resolution	40 μm	15 μm
Lateral resolution	90 μm	40 μm
Tissue penetration	2,5 mm	1 mm



IVUS-VH

Složení plátů v “edge oblastech”



IVUS –VH guided intervensence

(absolute values as indicated±SD)	(IVUS-guidance)		(IVUS-guidance) (IVUS-documentary)		
	Further intervention (n=29)	No further intervention (n=25)	(n=54)	(n=46)	
Mean stent CSA, mm ²	7.56±1.71	7.40±2.27	7.52±1.94	7.02±2.44	<0.05
Average reference lumen CSA, mm ²	8.11±2.94	8.01±3.00	8.16±3.04	8.06±2.02	NS
Minimal stent CSA, mm ²	6.46±1.99	6.21±1.51	6.42±1.59	5.71±1.79	<0.05
Stent under-expansion index	0.80±0.16	0.77±0.19	0.79±0.20	0.67±0.33	<0.05
Minimal stent diameter, mm	2.54±0.45	2.47± 0.41	2.48±0.43	2.31±0.40	<0.05
Maximal stent diameter, mm	3.77±0.43	3.69±0.40	3.76±0.46	3.54±0.57	<0.05
Proximal stent edge					
Fibrous tissue, %	61 ±11	58 ±13	57±11	52±14	<0.05
Fibro-fatty tissue, %	21±7	16±7	18±6	8±6	<0.05
Necrotic core, %	9±7	16±8 [‡]	15±8	27±11	<0.05
Dense calcium, %	9±6	10±6	10±6	13±9	NS
Plaque burden, %	34±10	36±9	35±13	48±11	<0.05
Minimal lumen area, mm ²	6.33±2.03	6.21±2.73	6.26±2.98	6.01±1.76	NS
Distal stent edge					
Fibrous tissue, %	60±16	62±13	61±18	49±21	<0.05
Fibro-fatty tissue, %	13±10	10±9	11±9	6±5	<0.05
Necrotic core, %	14±9	17±10	17±11	23±11	<0.05
Dense calcium, %	13± 9	10±6	11±7	22±18	<0.05
Plaque burden, %	31±11	34±9	33±8	42±12	<0.05
Minimal lumen area, mm ²	6.17±2.43	6.01±3.34	6.06±3.23	5.53±1.85	<0.05

‡ P value for the 29 patients in Group 1 with further intervention versus the 25 pts without further intervention in Group 1=NS ; *P value for Group 1 total versus Group 2.

Rizikové skóre plátu na základě IVUS-VH analýzy “Liverpool score”

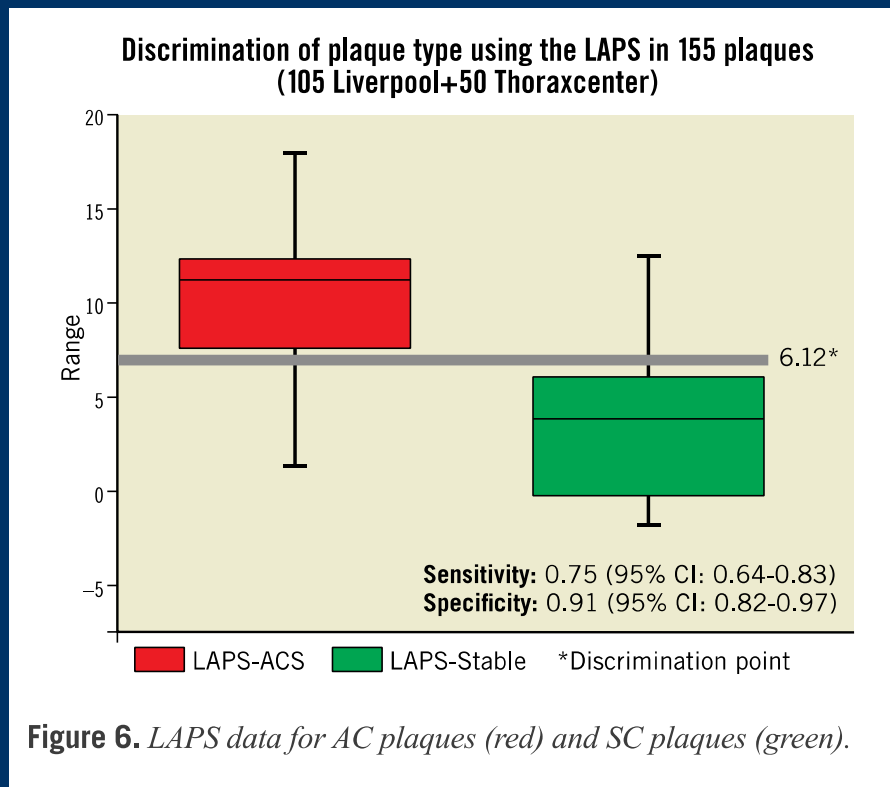
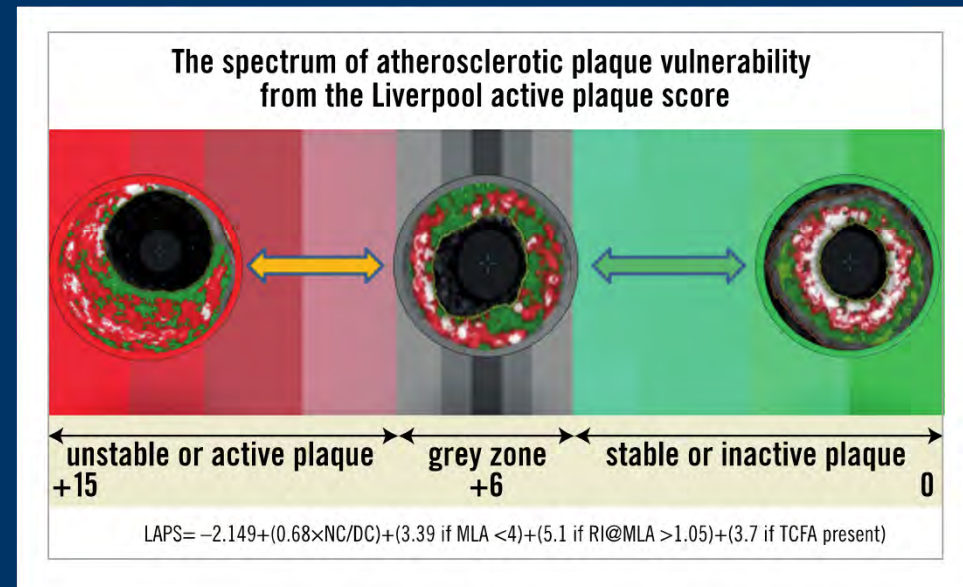
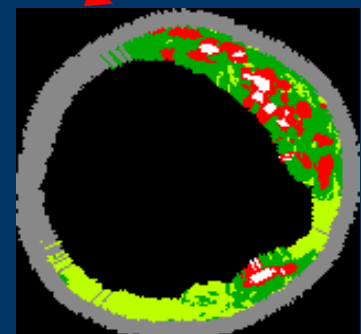
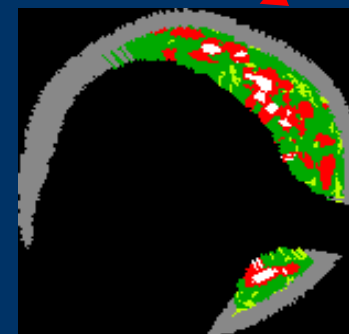
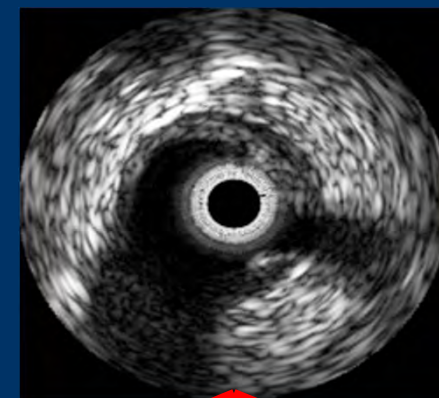
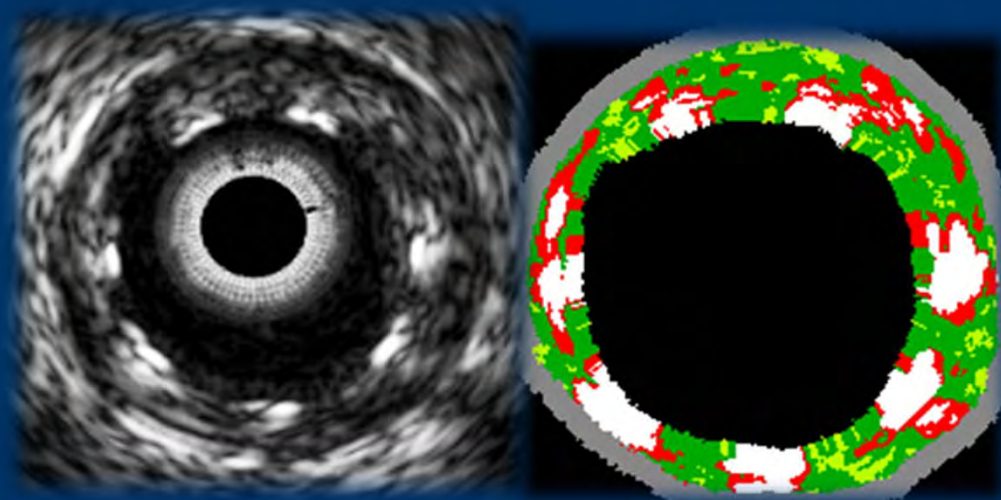


Figure 6. LAPS data for AC plaques (red) and SC plaques (green).

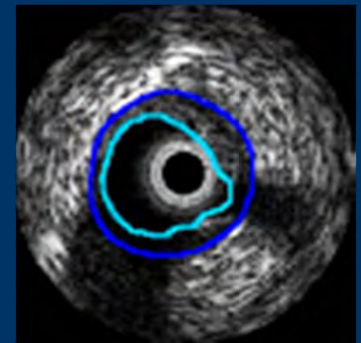
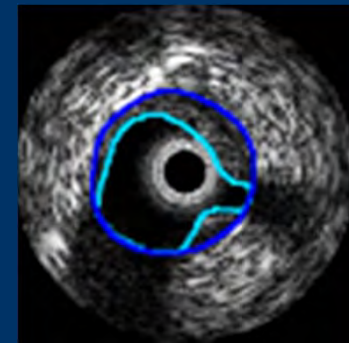
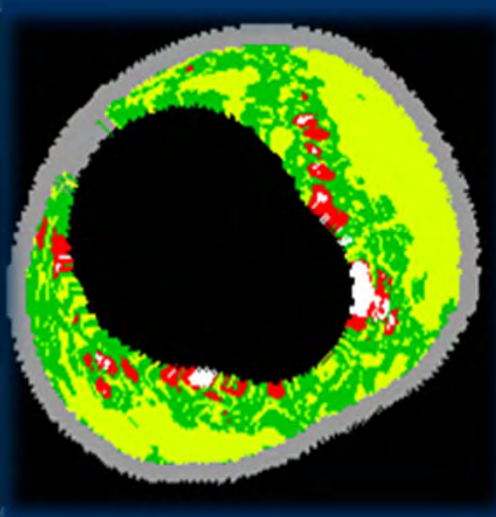
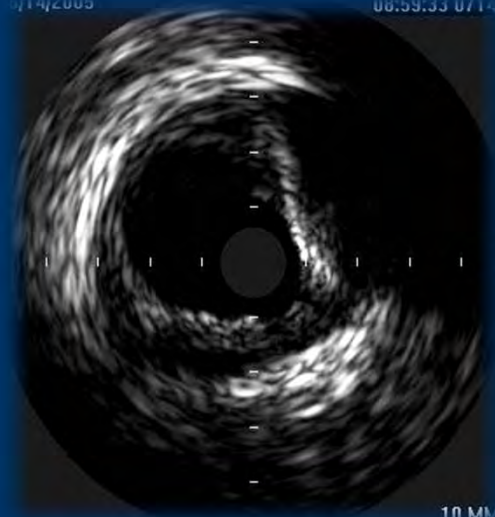


$$LAPS = -2.149 + (0.68 \times NC/DC) + (3.39 \text{ if } MLA < 4) + (5.1 \text{ if } RI \text{ in } MLA > 1.05) + (3.7 \text{ if TCFA present})$$

Limitace IVUS-VH



07/14/2005 08:59:33 07/14



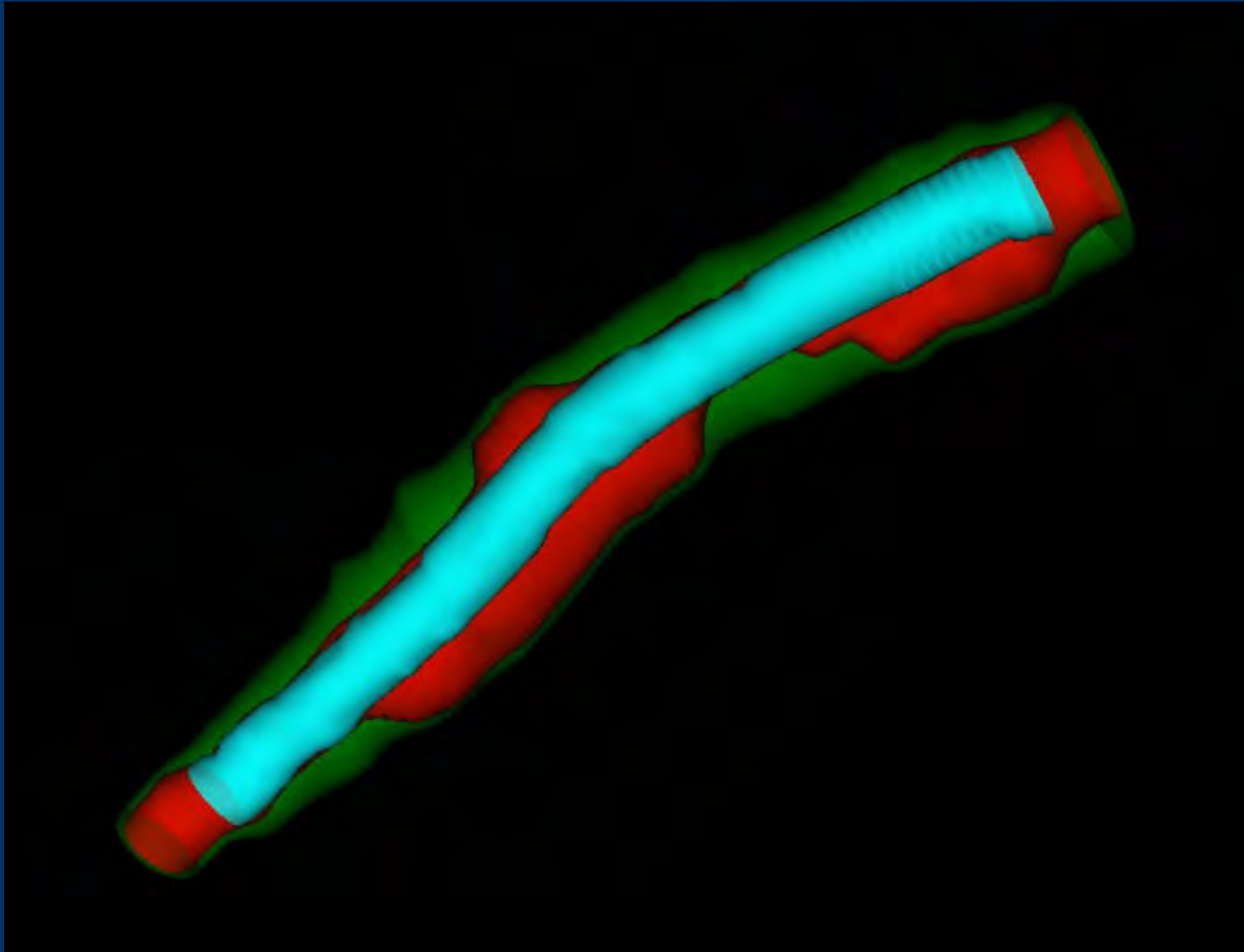
3D analýza plátů v 5 mm segmentech “chunks”



Steps to dividing vessel wall into 5mm chunks.

1. Obtain interval spacing of slices from DICOM file.
2. Number of slices for each chunk = $5\text{mm} / \text{spacing}$.
3. Start from first slice and divide the whole vessel into 5mm chunks until reaching the last slice.
4. Exclude slices intersecting branches from each chunk.

Pozdní malapozice ve stentu po predilataci léze DEB



Endothelial shear stress (ESS)

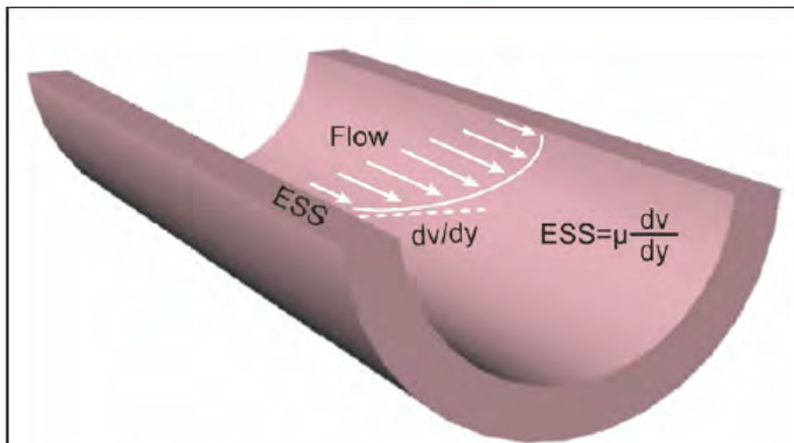
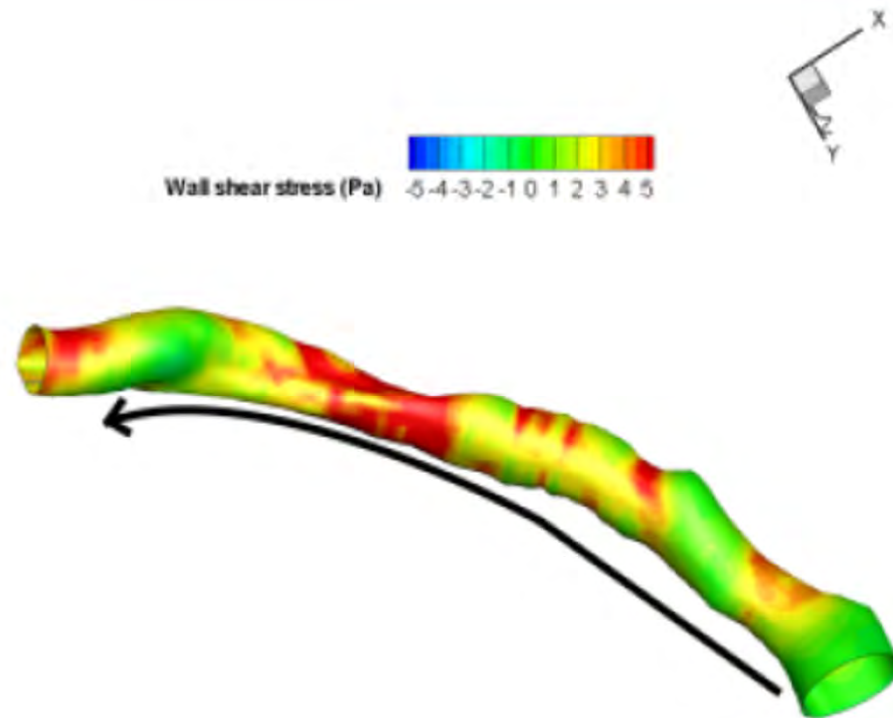
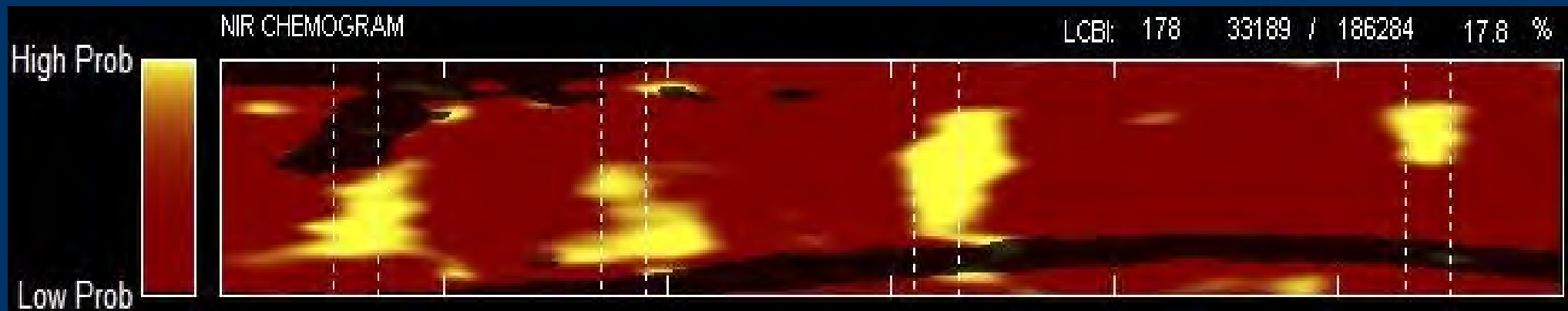


Figure 1 Definition of ESS

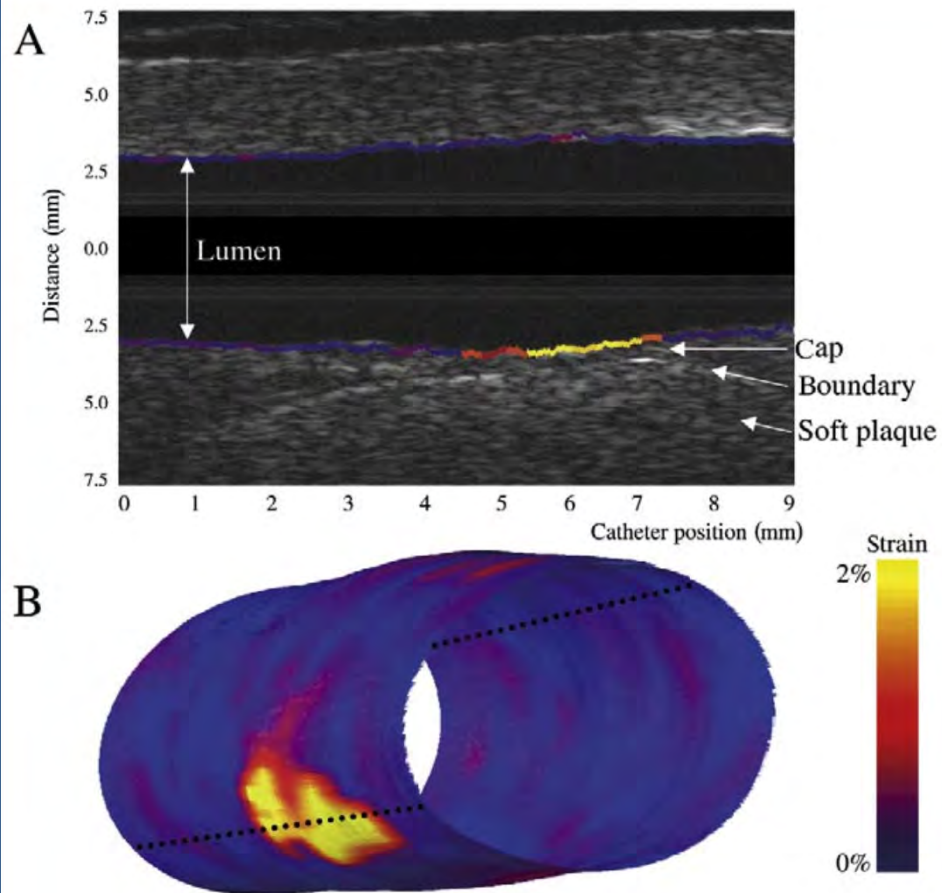
Endothelial shear stress (ESS) is proportional to the product of the blood viscosity (μ) and the spatial gradient of blood velocity at the wall (dv/dy).



Near infrared spectroscopy –NIRS



Napětí v plátu



B

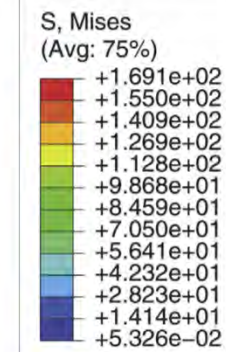
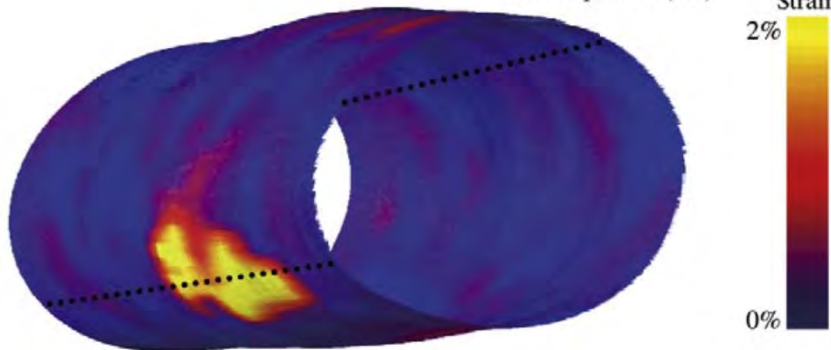


Figure 3 Contour map of von Mises stresses in half cross-section of a plaque model with intermediate intima stiffness. The highest stresses are in the cap and the peak stress values in the midcap and shoulder region are similar.

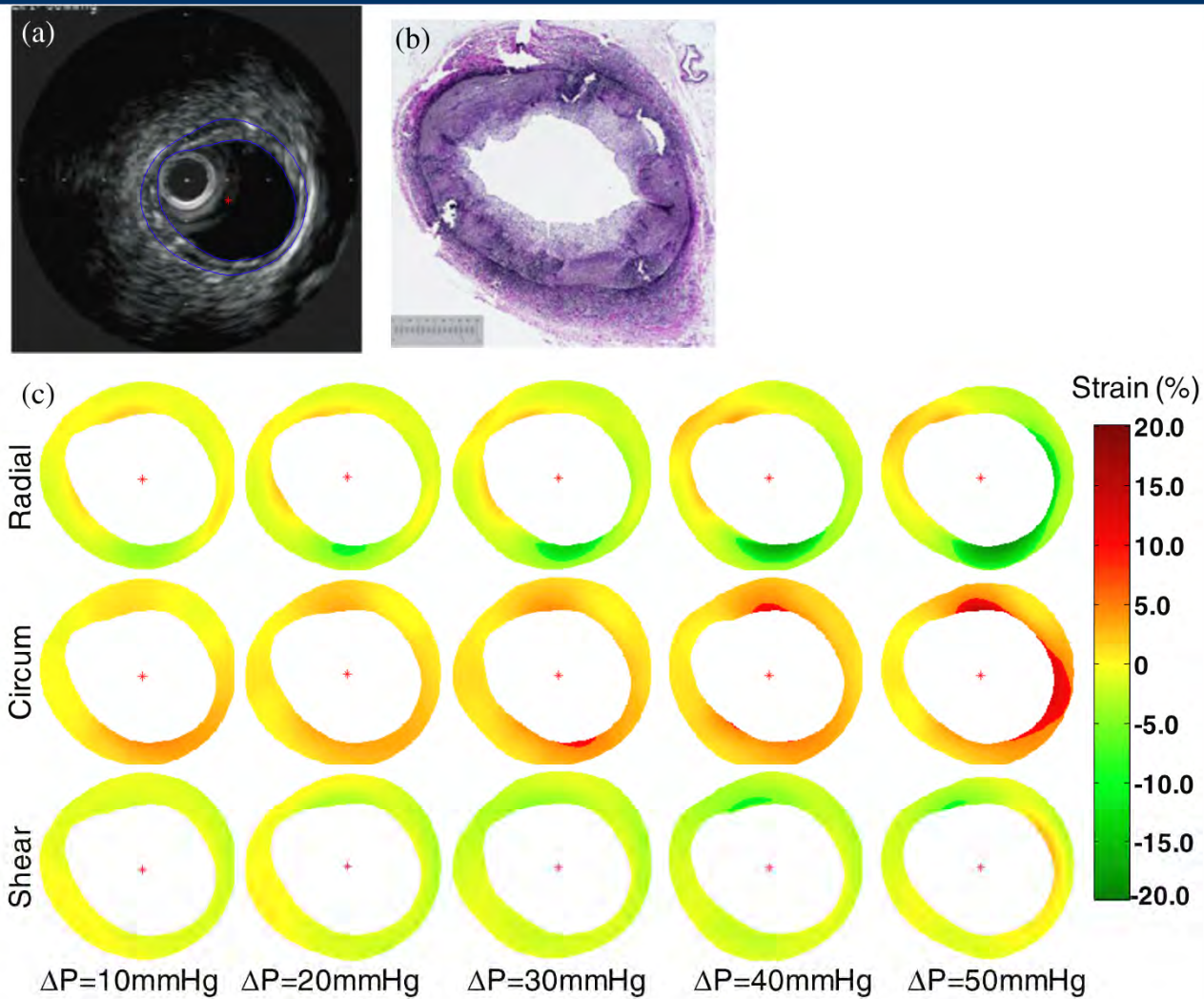
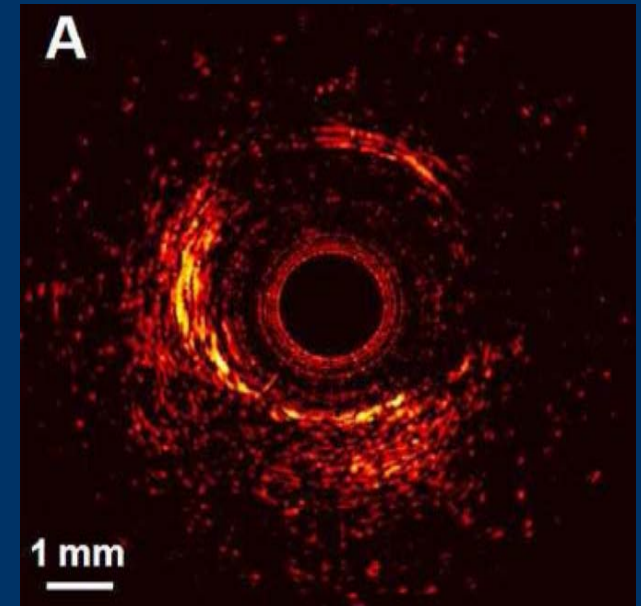
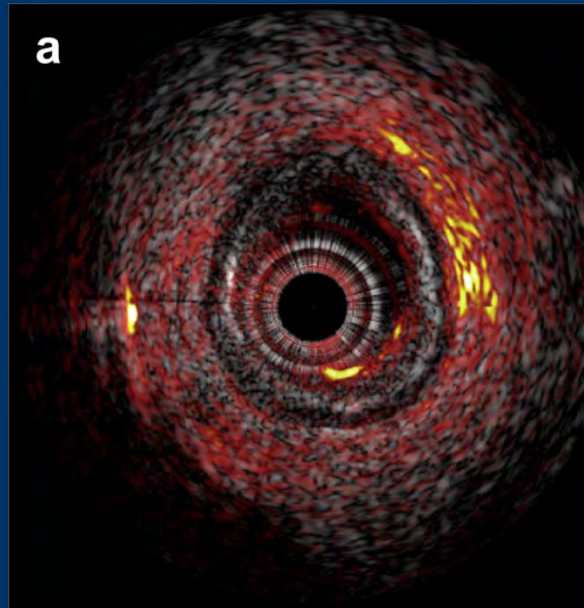
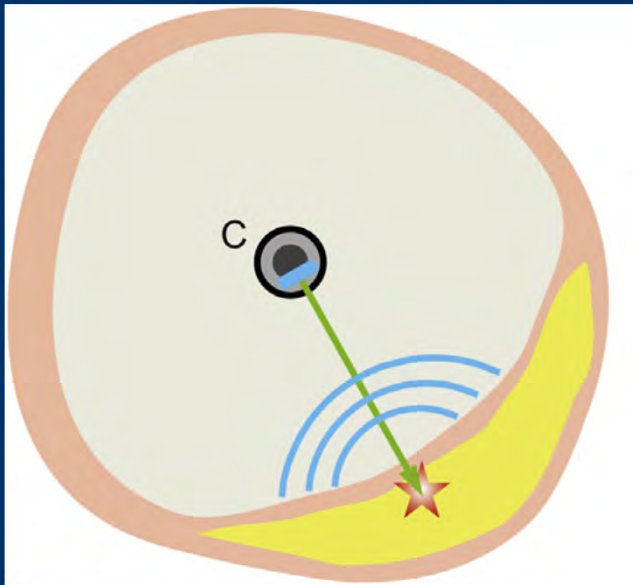


Figure 1. Site 1 on RCA1. (a) IVUS echogram, the lumen and media–adventitia boundaries are identified; (b) VVG histology section ($\times 2$); (c) radial, circumferential and shear strain under increasing pressure differences.

Intravascular ultrasound-guided photoacoustic imaging IVPA



Rozlišení fibrózní, lipidové a kalcifikované tkáně. Při amplifikaci lze zobrazit i makrofágy

Jansen K. *Ultrasound in Med. & Biol.*, 2014, Wang B. *Ultrasound Med Biol.* 2012; 38:2098–2103

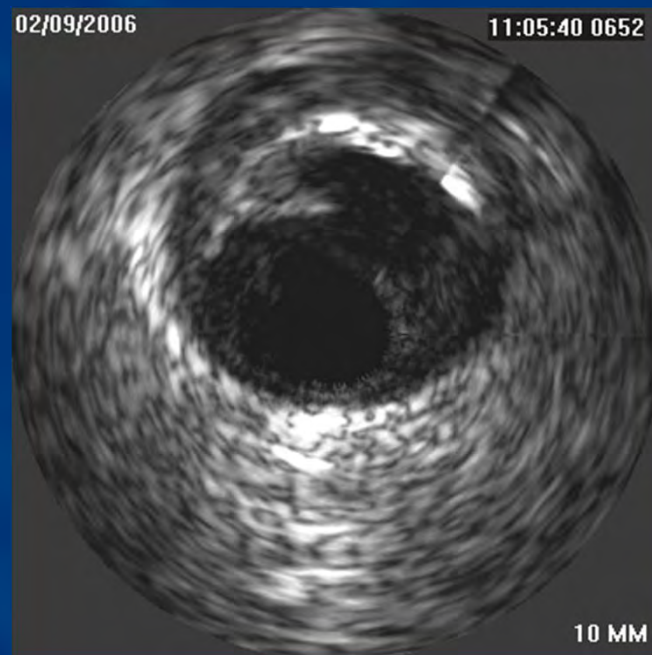
Závěry

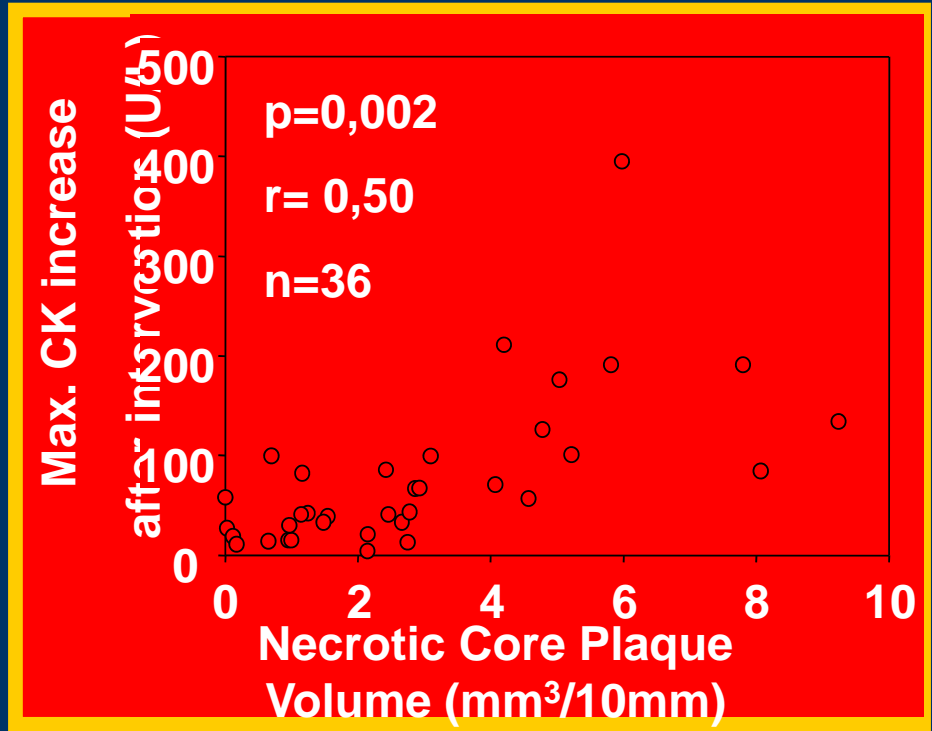
- IVUS je stále platnou technikou v každodenní praxi s indikací IIa pro kmen ACS a IIb pro ostatní tepny. Kategorie se však bude nejspíše měnit na základě posledních studií
- Hodnocení hemodynamické významnosti je jistě dominantou funkčních metod jakými jsou FFR a iFR
- Řadu indikací pro IVUS jistě převezme OCT
- IVUS stále zůstává podstatnou částí nových metod hodnocení rozsahu a rizikového profilu aterosklerotických plátů



Indikace rutinního IVUS v roce 2014

- Hodnocení angiograficky nejasných nálezů
- Hodnocení hemodynamické významnosti stenóz
- Vedení koronárních intervencí
- Detekce komplikací koronárních intervencí





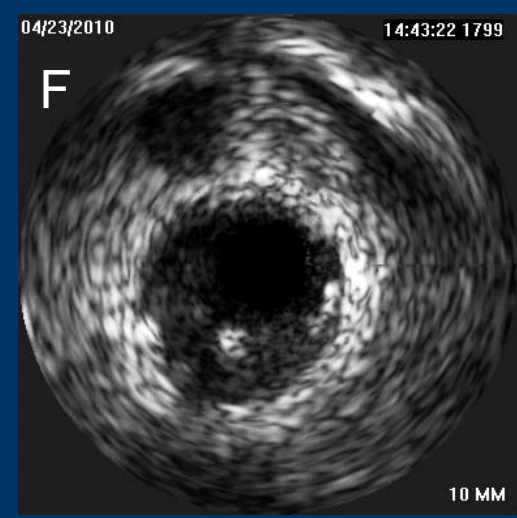
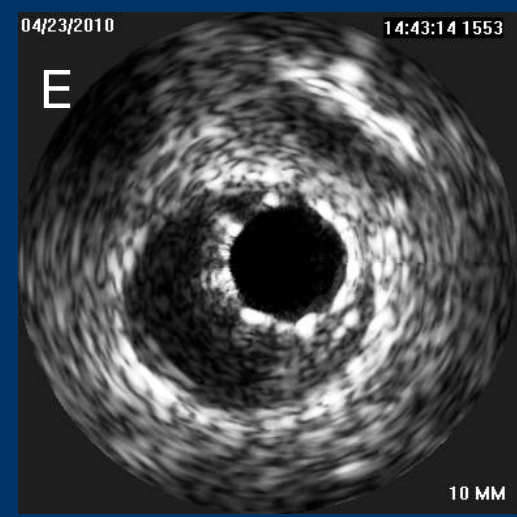
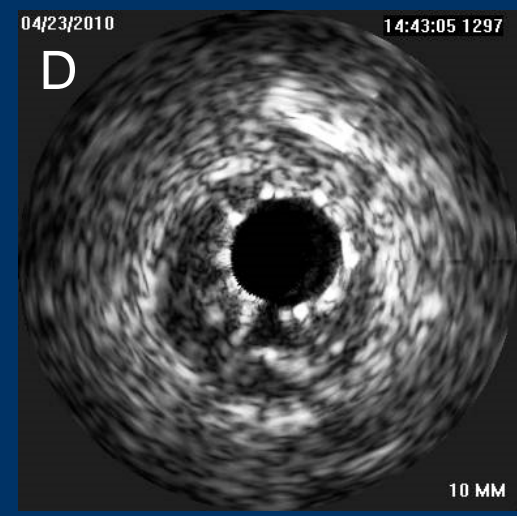
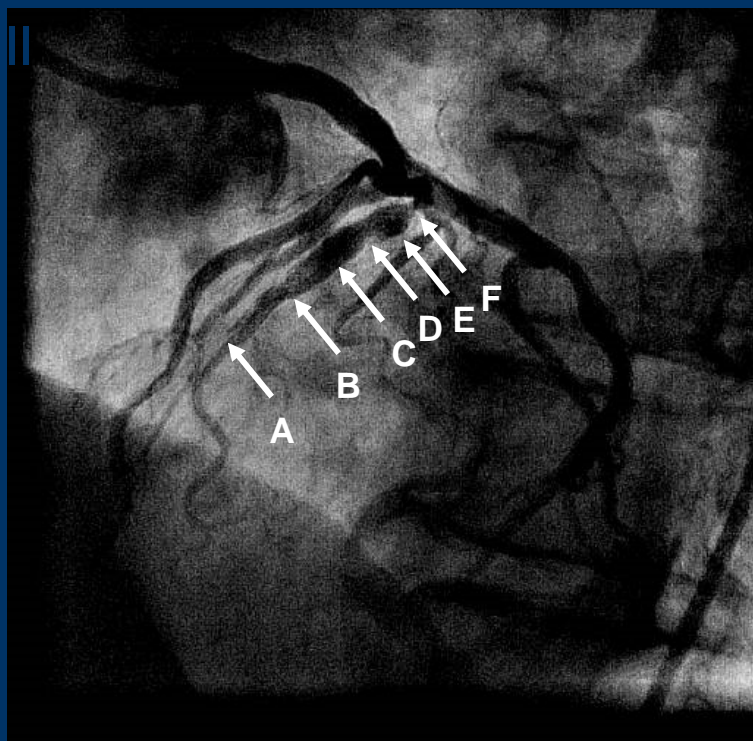
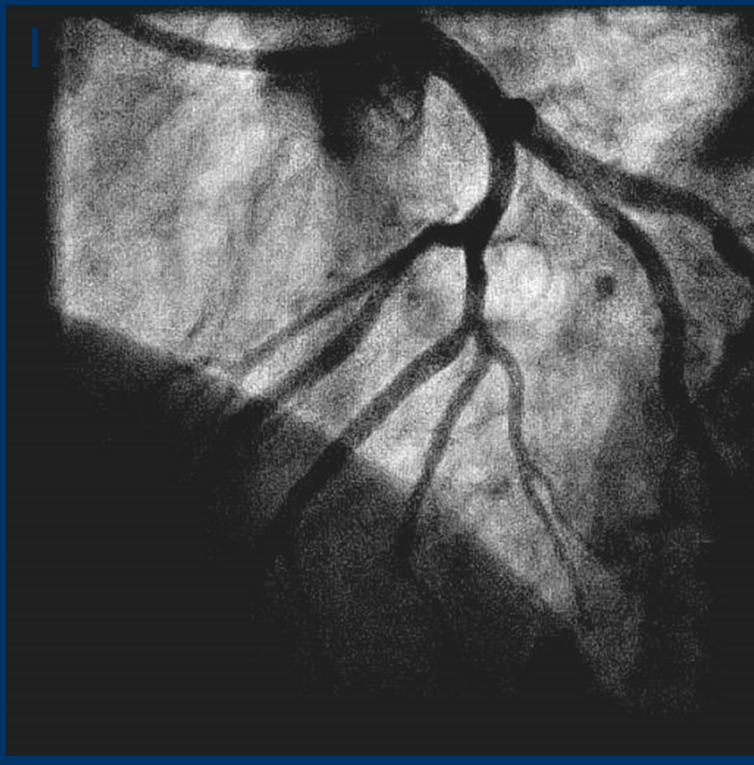
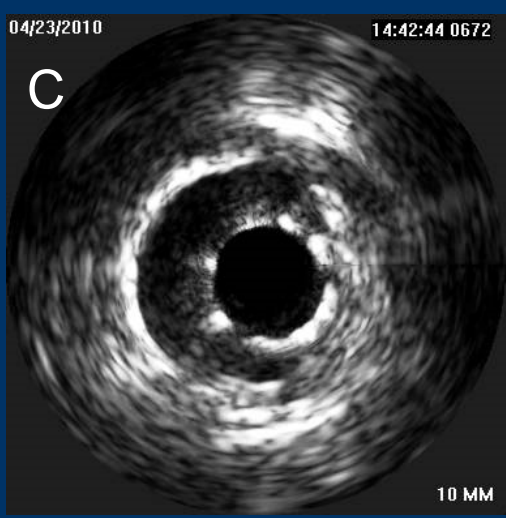
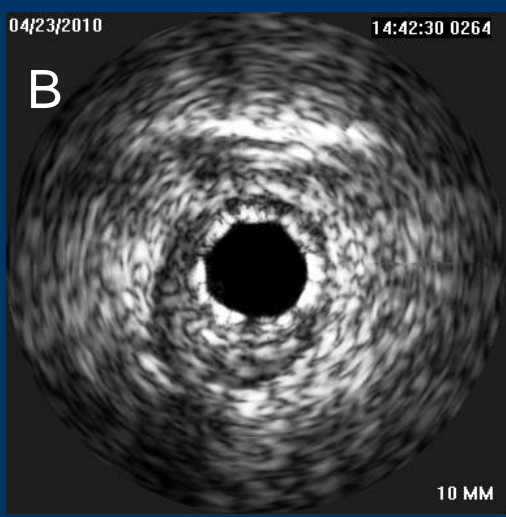
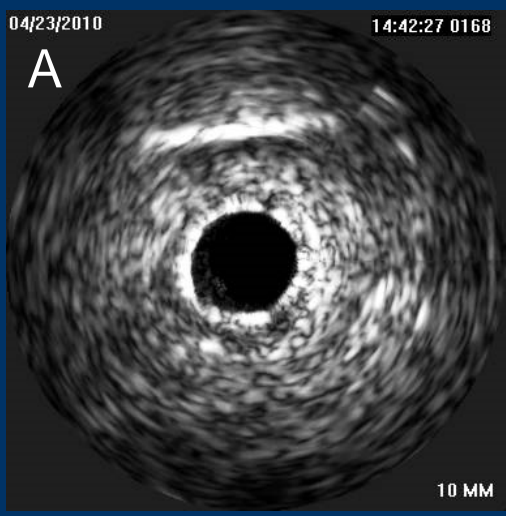
Erbel, PCR, 2006

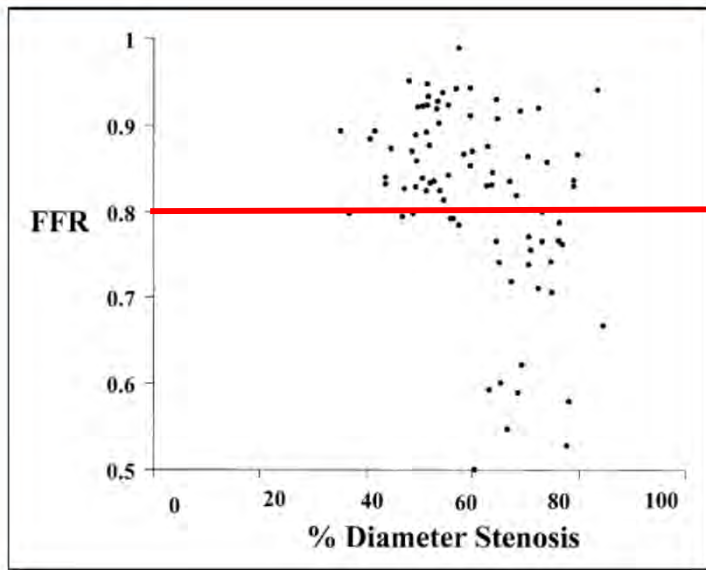
Postavení IVUS v katlabu 2011

- Hodnocení hemodynamické významnosti
- Hodnocení bifurkačních lézí
- Wall shear stress
- IVUS vedení intervencí
- Nejasné angiografické nálezy

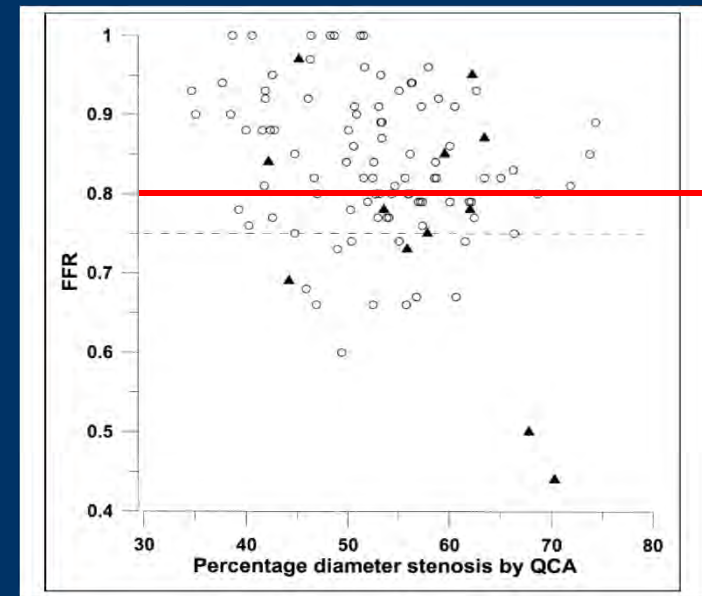
Postavení IVUS v katlabu 2011

- **Hodnocení hemodynamické významnosti**
- Hodnocení bifurkačních lézí
- Wall shear stress
- IVUS vedení intervencí
- Nejasné angiografické nálezy

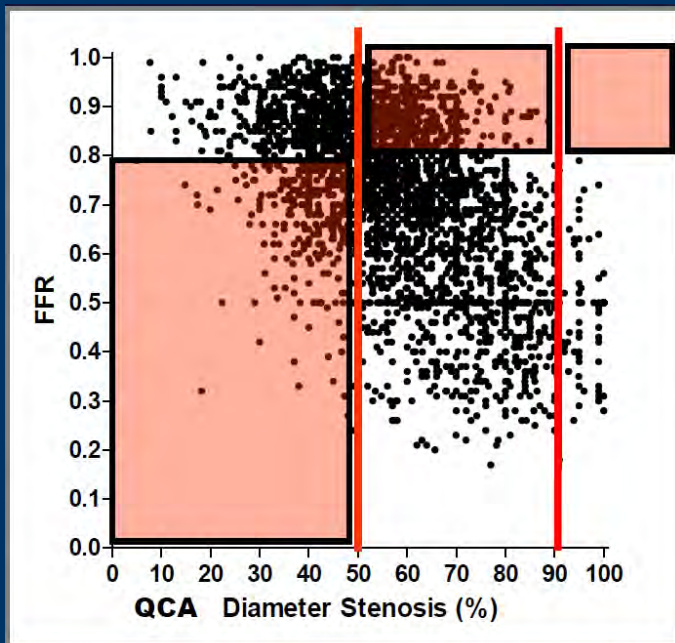




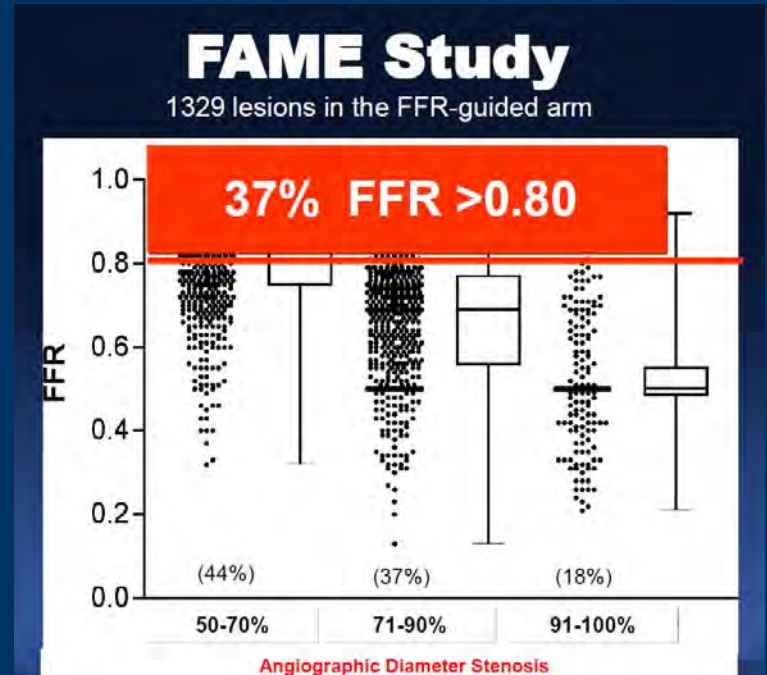
Fisher JJ, Am J Cardiol 2002;90:210-215



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



Courtesy of Bernard De Bruyne, MD, PhD,





Flow Chart

FFR-Guided

PCI performed on indicated lesions only if FFR ≤ 0.80

Lesions warranting PCI identified

Angio-Guided

PCI performed on indicated lesions

Randomized

Primary Endpoint

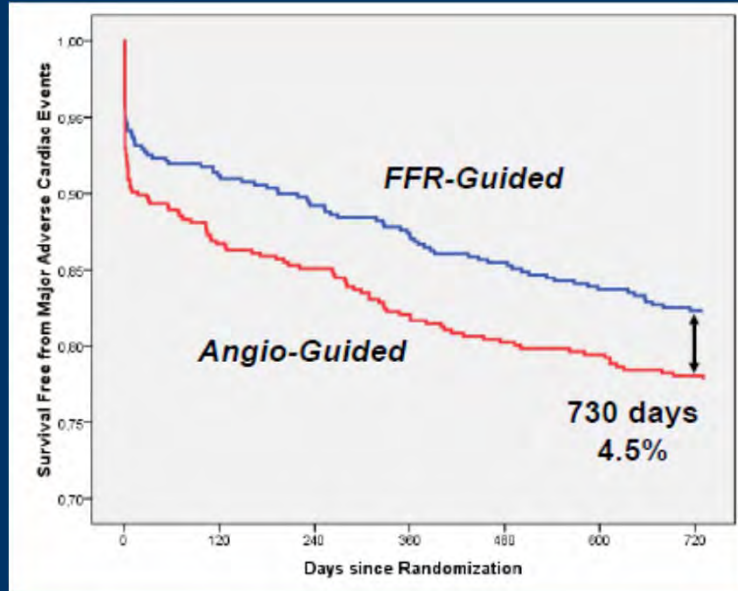
Composite of death, MI and repeat revasc. (MACE) at 1 year

Key Secondary Endpoints

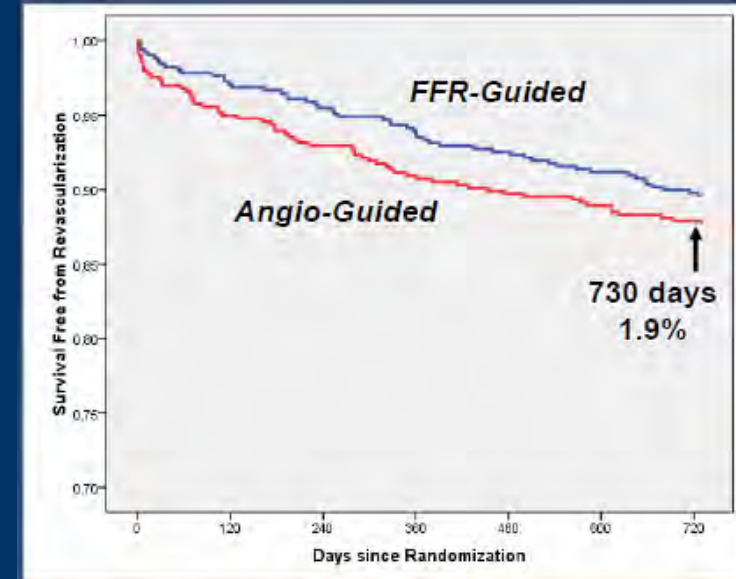
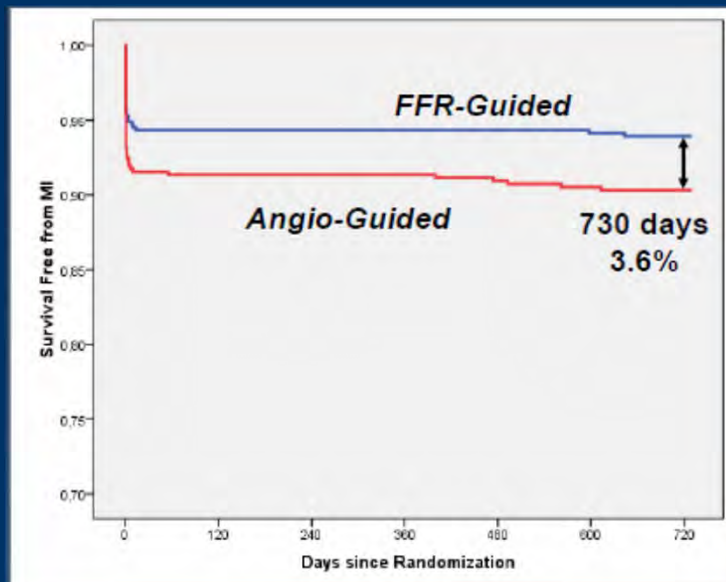
Individual rates of death, MI, and repeat revasc., MACE, and functional status at 2 years

FAME - výsledky

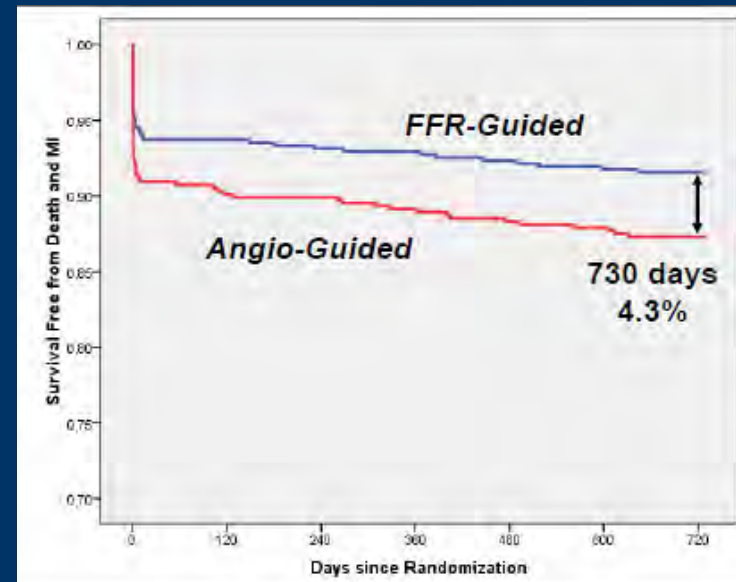
Bez
MACE



Bez IM



Bez
revask.

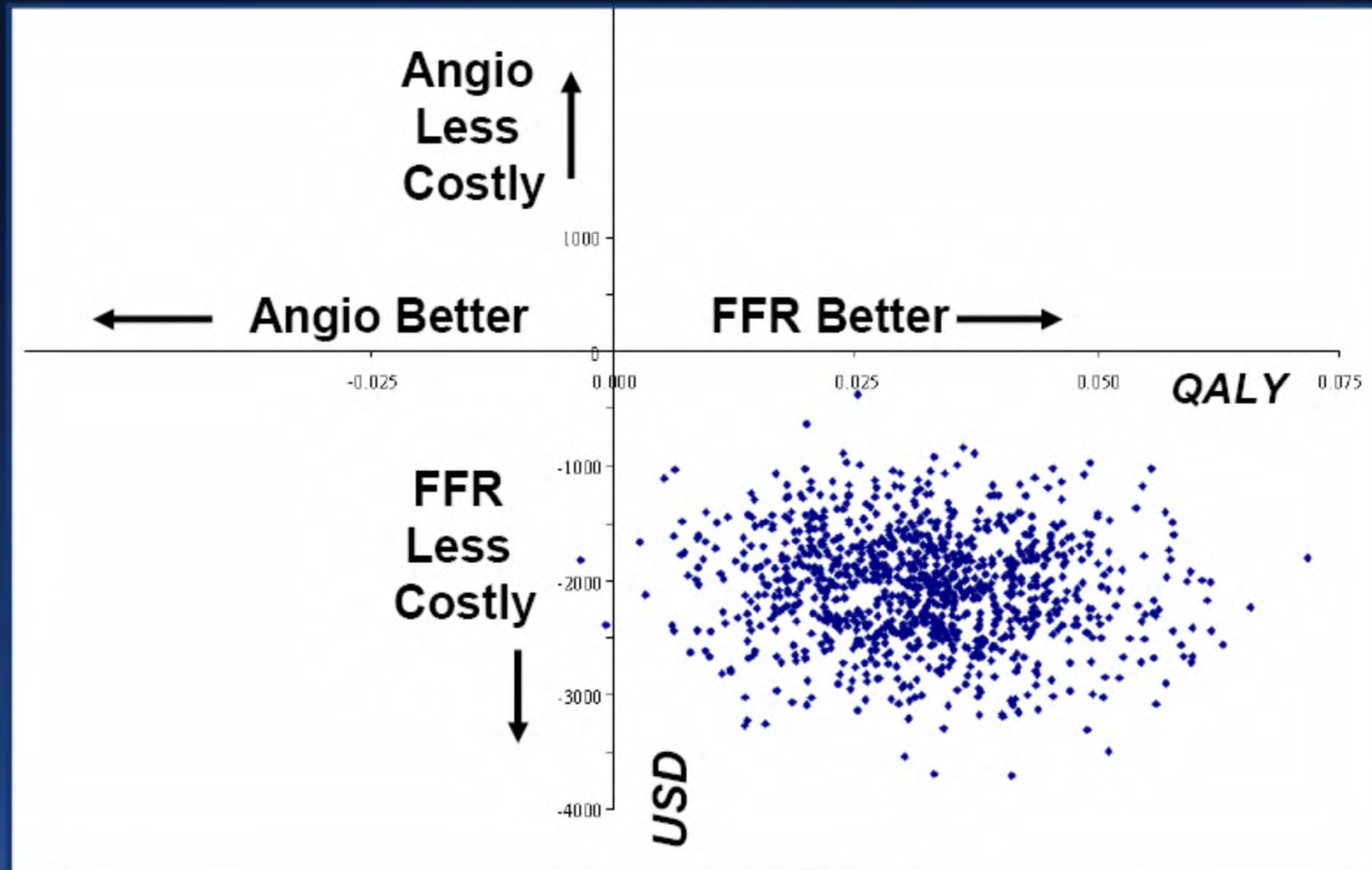


Bez IM
či úmrtí



1 Year Economic Evaluation

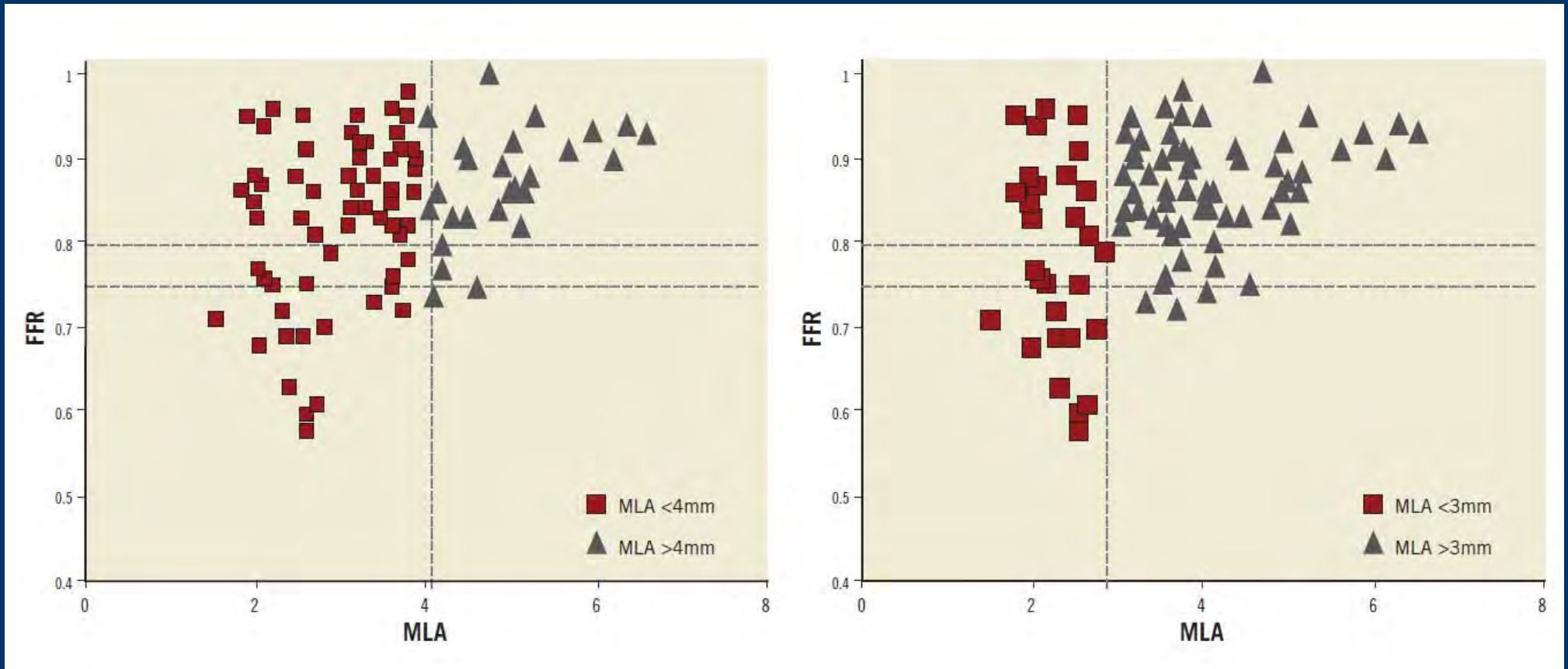
Bootstrap Simulation



IVUS a hemodynamická významnost

Author	Description	Methods	No of patients	Result
Briguori	Stenoses 40-70%	IVUS vs. FFR	43	<i>FFR < 0,75 correlates with :</i> <ul style="list-style-type: none"> - MLA ≤ 4 mm² - MLD ≤ 1,8 mm - PB > 70% - léze > 10 mm
Abizaid	Stenoses > 50%	IVUS vs. CFR	73	<i>CFR ≥ 2 correlates with:</i> <ul style="list-style-type: none"> - MLA ≥ 4 mm² - MLD ≥ 2 mm
Nishioka	Consecutive IVUS investigations	IVUS vs. SPECT	79	<i>Positive SPECT correlates with:</i> <ul style="list-style-type: none"> - MLA ≤ 4 mm² - PB > 73% - LAS > 59%
Takagi	Consecutive IVUS investigations	IVUS vs. FFR	42	<i>FFR < 0,75 correlates with:</i> <ul style="list-style-type: none"> - MLA ≤ 3 mm² - LAS > 60%
PROSPECT	ACS patients	IVUS a MACE	700	MLA 4 mm² is predictor of MACE together with PB > 70% a TCFA

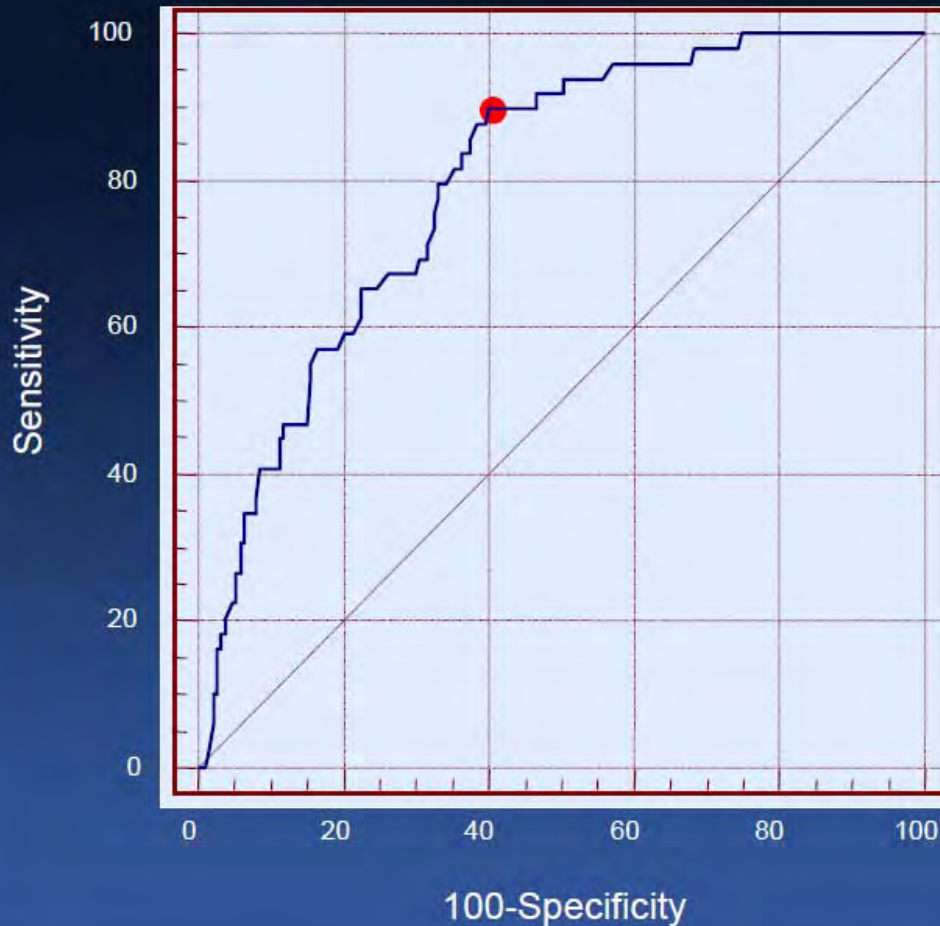
Ben Dor: FFR vs. MLA



In Epicardial Artery

IVUS MLA matched with FFR <0.80 (n=236)

SLIDE_BACK_수정본



**New Cut-off =
2.42mm²,**

AUC=0.800,
95% CI=0.742-0.848

Sensitivity=90%
Specificity=60%
PPV=37%
NPV=96%
Accuracy=68%

Kang SJ, et al, Circ Cardiovasc Interv. 2011;4: 65-71

MLA vs. SPECT

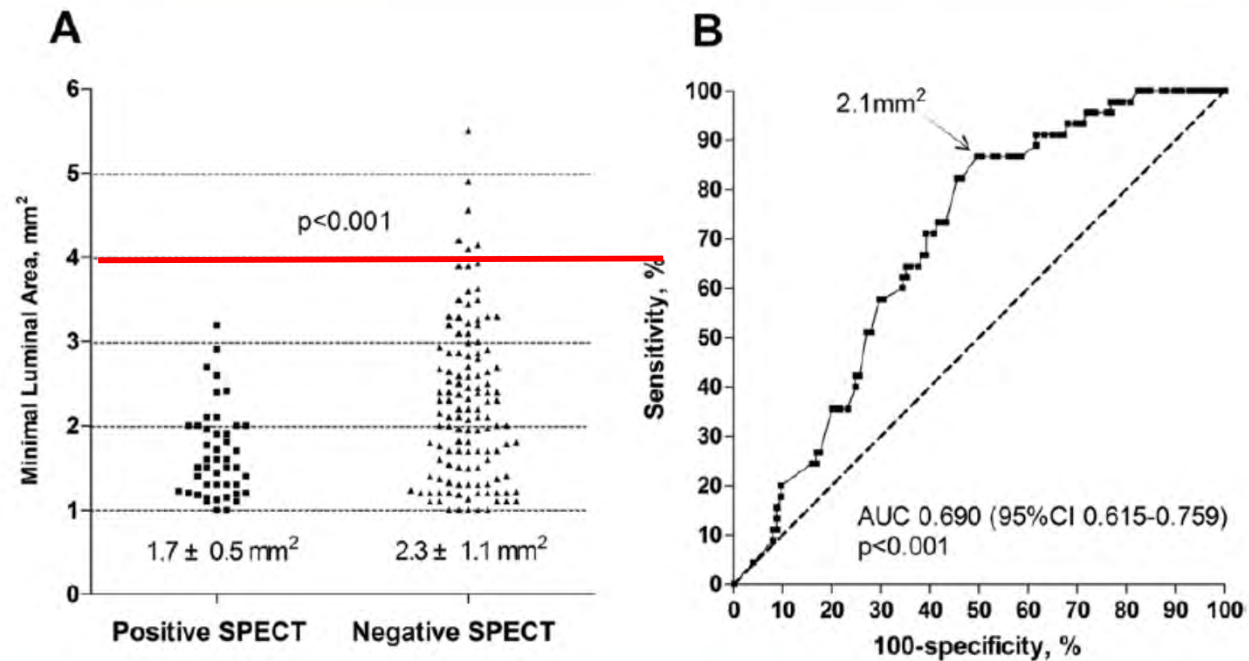


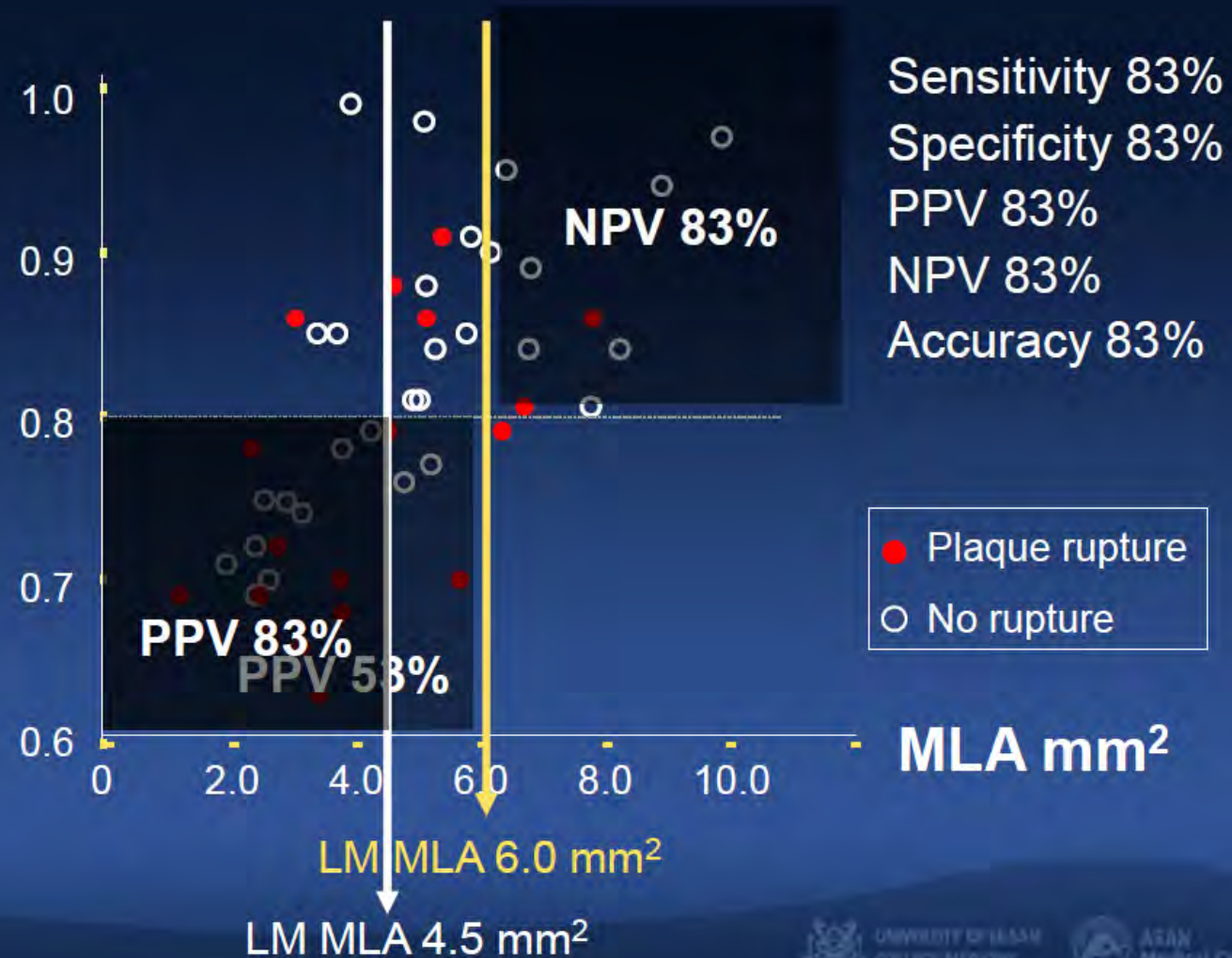
Figure 1. SPECT Versus IVUS Measured MLA in All Lesions

Scatterplot (A) and receiver-operator characteristic curve (B) of single-photon emission computed tomography (SPECT) versus intravascular ultrasound (IVUS)-measured minimal luminal area (MLA) in all lesions. AUC = area under the curve; CI = confidence interval.

The IVUS MLA (4.5mm^2) can predict FFR <0.8 in left main disease.

FFR >0.8

FFR <0.8



Nová doporučení

- FFR < 0,8¹:
 - MLA 2,4 mm² pro tepny 2,5-3,0 mm
 - MLA 2,7 mm² pro tepny 3,0-3,5 mm
 - MLA 3,6 mm² pro tepny > 3,5 mm
- FFR < 0,8² :
 - MLA 2,4 mm²
- SPECT³
 - MLA 2,1 mm²
- FFR < 0,8⁴ pro kmen ACS:
 - MLA 4,5 mm²

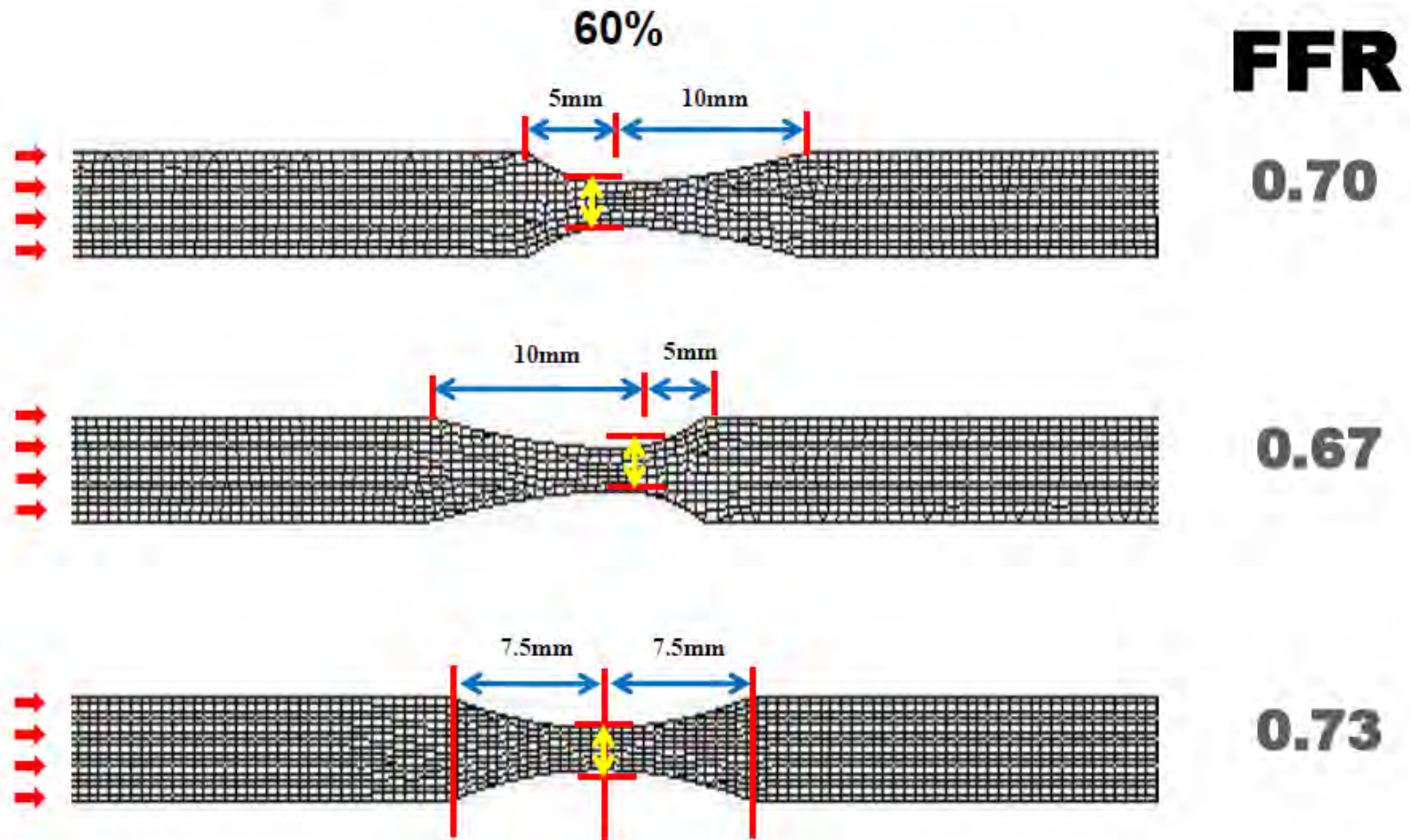
Nová doporučení

- FFR < 0,8¹:
 - MLA 2,4 mm² pro tepny 2,5-3 mm
 - MLA 2,7 mm² pro tepny 3,0-3,5 mm
 - MLA 3,6 mm² pro tepny > 3,5 mm

MLA je v průkazu hemodynamické významnosti prakticky nepoužitelné

- SPECT³
 - MLA 2,1 mm²
- FFR < 0,8⁴ pro kmen ACS:
 - MLA 4,5 mm²

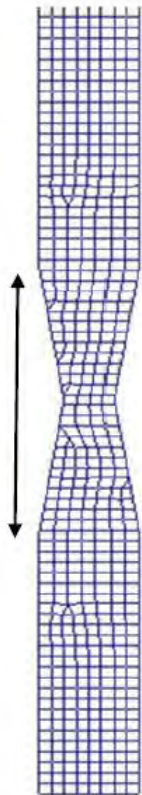
Lesion Eccentricity (longitudinal, cross-sectional)



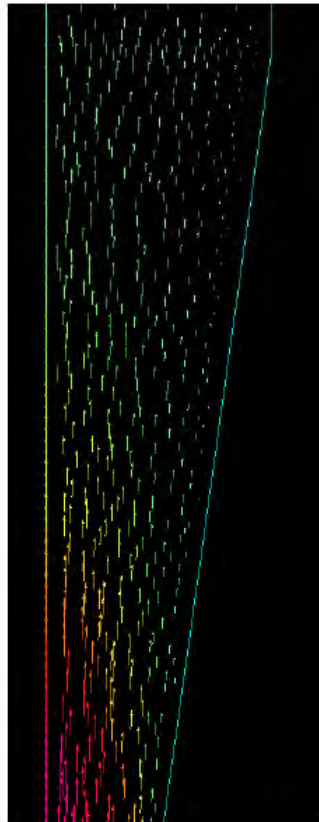
Different Surface Roughness

50%

20mm

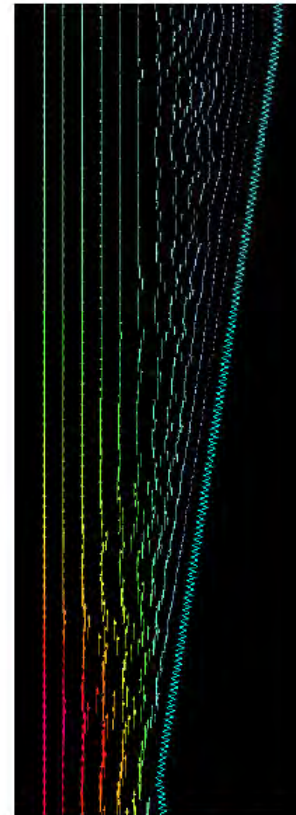


Control



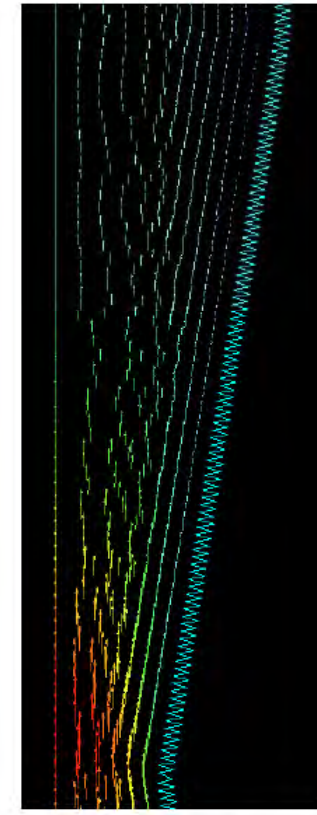
FFR : 0.72

Crease size
0.05mm



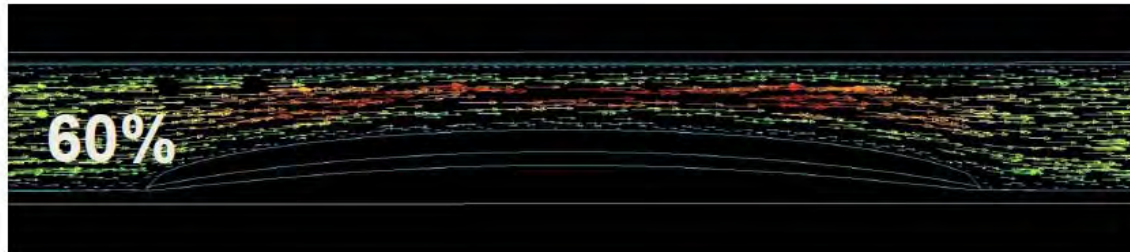
0.64

Crease size
0.1mm

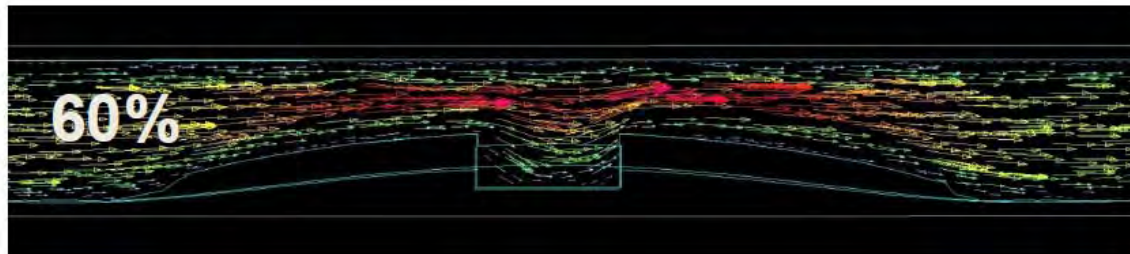


0.62

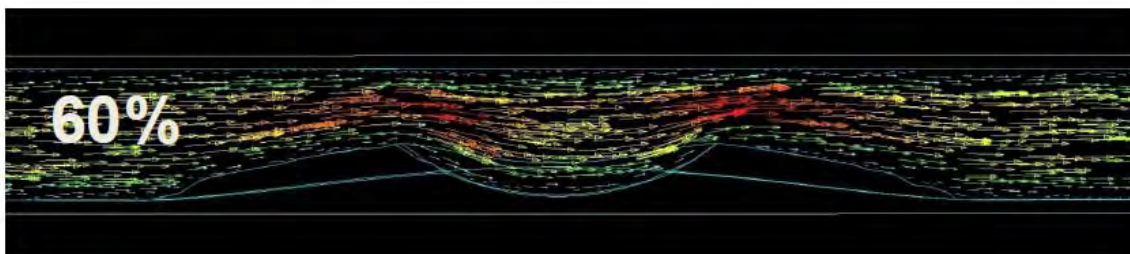
Presence of Plaque Rupture



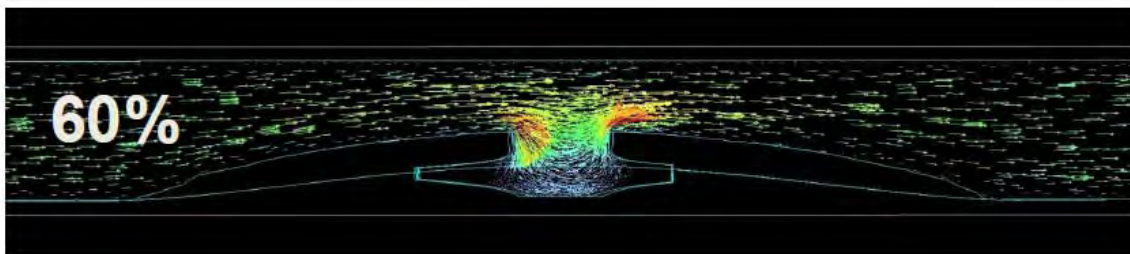
FFR : 0.81



0.79



0.74



0.70

FFR is influenced by Many Lesion Specific Factors

- Degree of diameter stenosis
- Reference vessel diameter
- Lesion morphology
- Eccentricity
- Lesion length
- Plaque burden, Plaque rupture
- Surface roughness
- Viscous friction, flow separation, turbulence, and eddies

Postavení IVUS v katlabu 2011

- Hodnocení hemodynamické významnosti
- **Hodnocení bifurkačních lézí**
- Wall shear stress
- IVUS vedení intervencí
- Nejasné angiografické nálezy

Lokalizace plátu v oblasti bifurkací

- Plát se nikdy nevyskytuje v oblasti kariny
- Z hemodynamických důvodů se plát tvoří na protilehlé straně než je karina



Výskyt plátu v karině u různých typů bifurkací

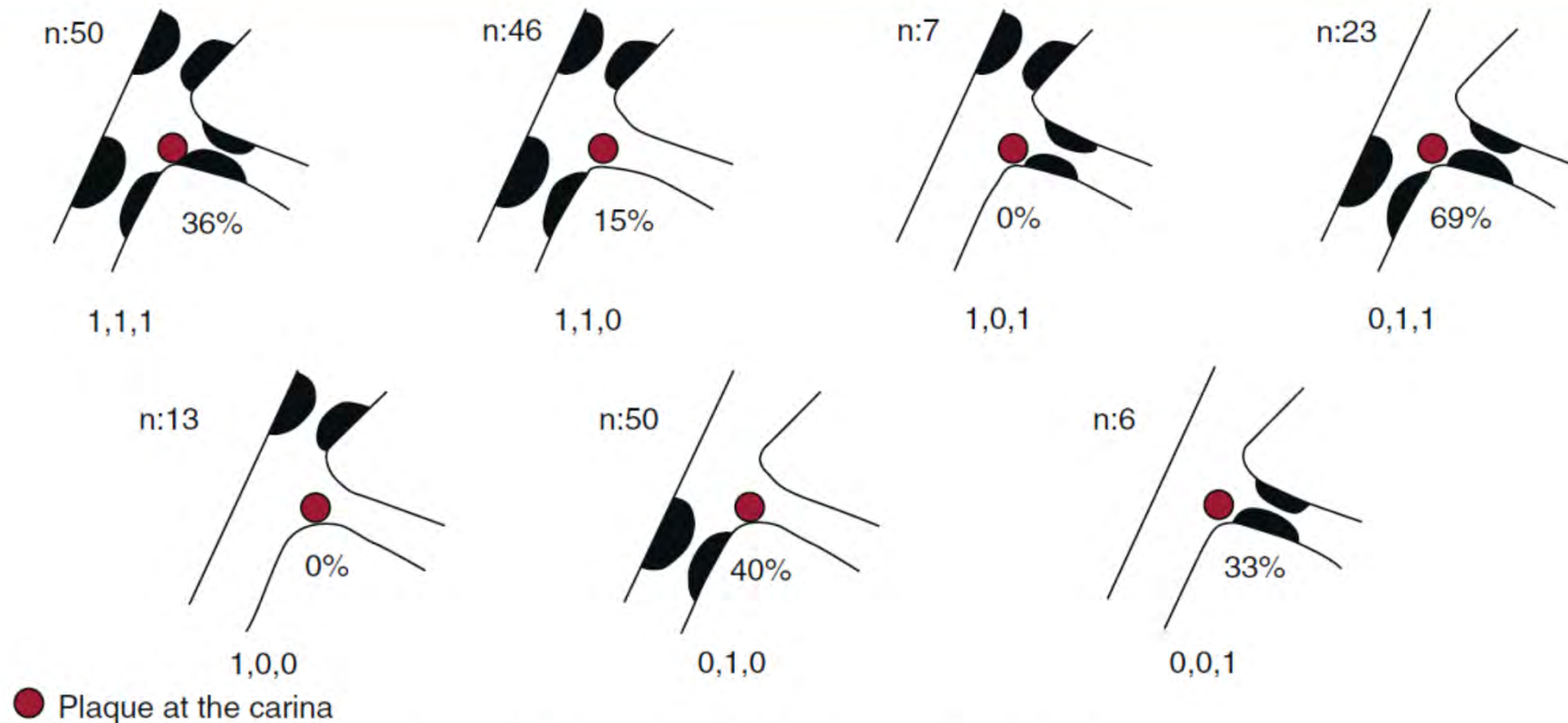
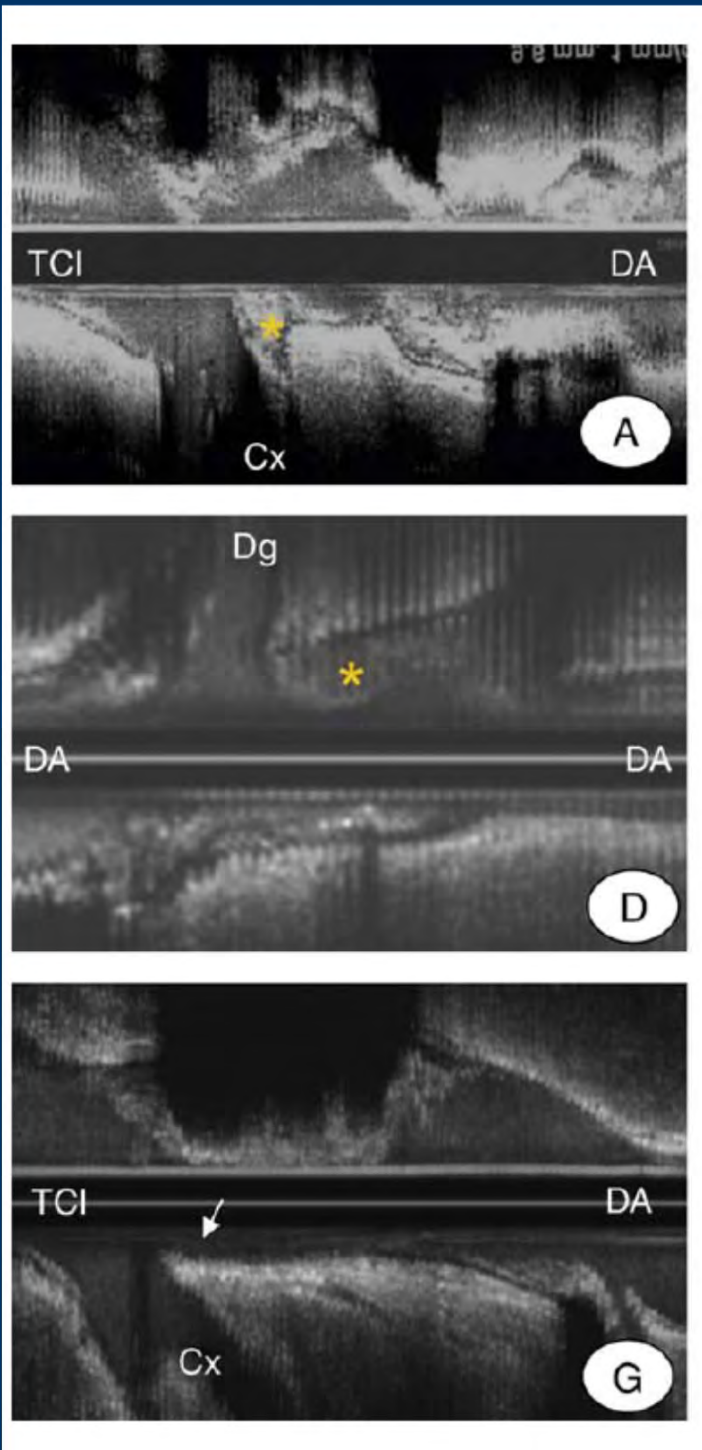


Figure 4. Prevalence of plaque at the carina according to bifurcation type.

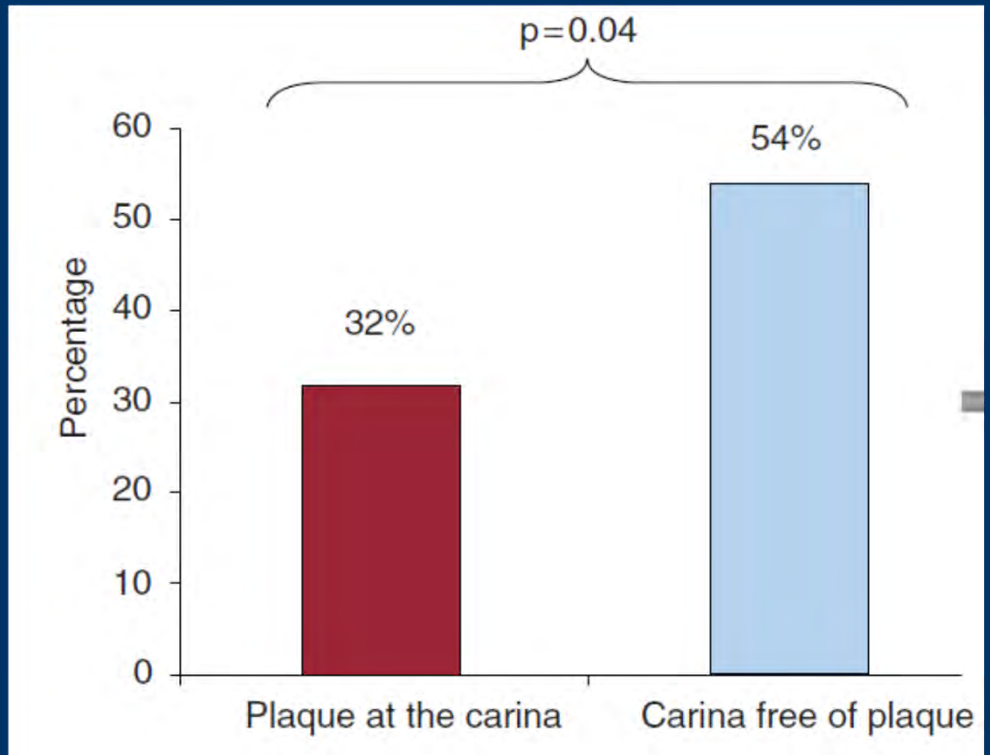
PCI u bifurkačních lézí

- Klasické paradigma zhoršení průtoku v SB po stentingu MB:
 - komprese plátu v ostiu postranní větve při implantaci stentu do hlavní větve, přičemž větší riziko tohoto fenoménu je u difúzního postižení ostia SB
 - přesun plátu z MB do SB při dilataci v hlavní větvi (fenomén sněžného pluhu)
 - překrytí ostia SB stentem implantovaným v MB

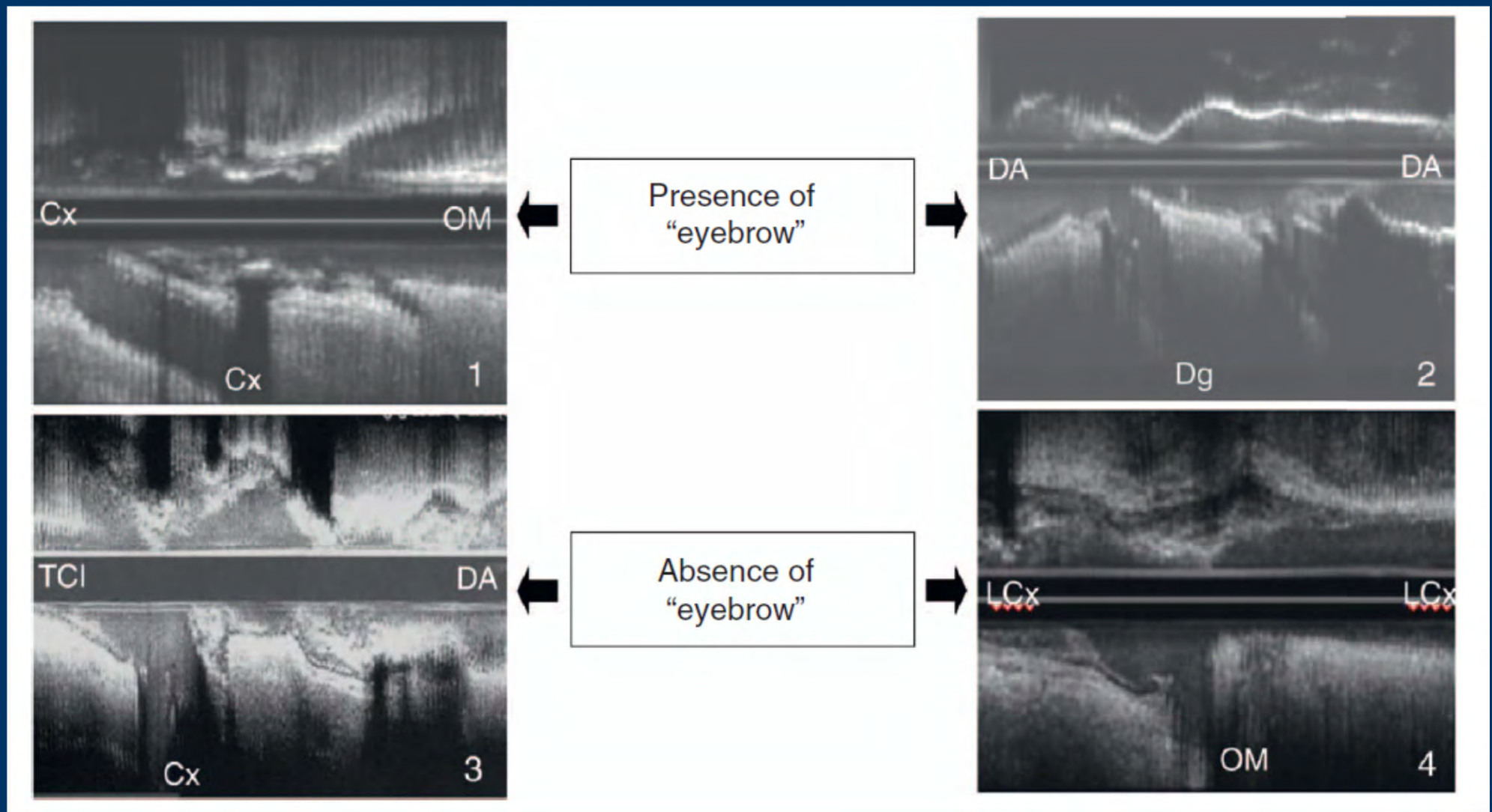
Typy lokalizace plátu u bifurkací



Vztah lokalizace plátu a zhoršení průtoku v SB po stentingu v MB

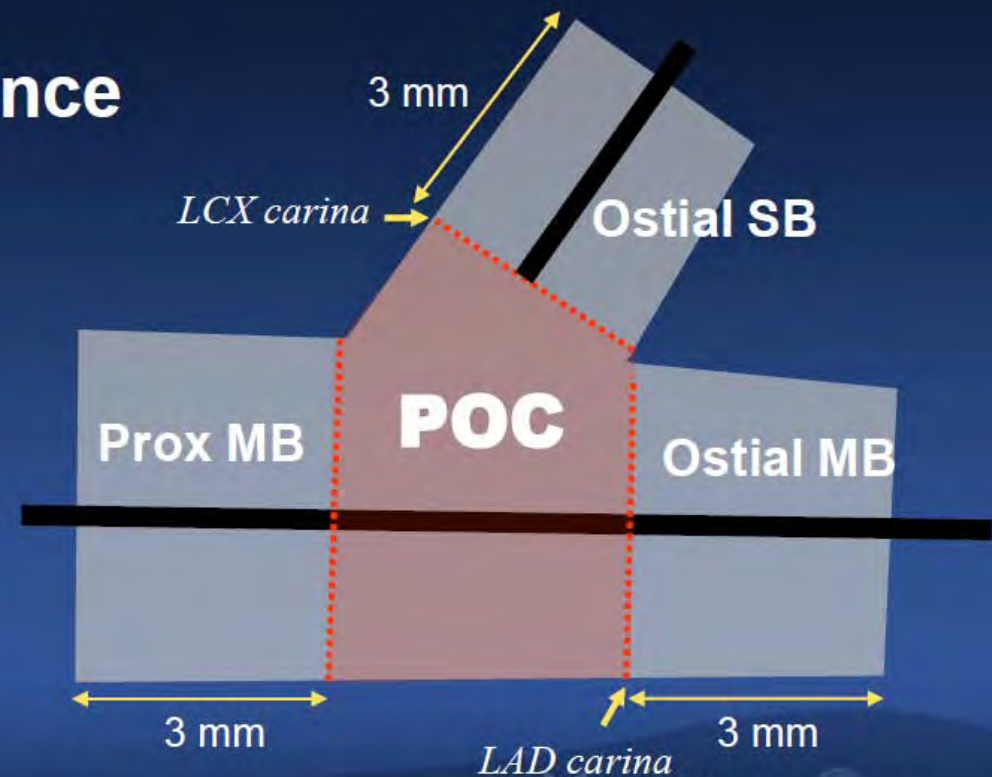


Typ kariny a riziko jejího přesunu do SB



Four Segments of IVUS Measurement

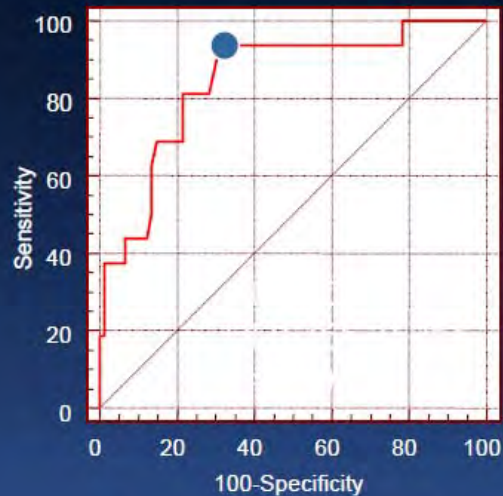
- MB Ostium
- SB Ostium
- Polygon of Confluence
- Proximal MB



Kang SJ. Am J Cardiol 2011

IVUS MLA Cut-Off matched with SB FFR (<0.80)

MLA of SB ostium



Cut-off value;
2.4mm²

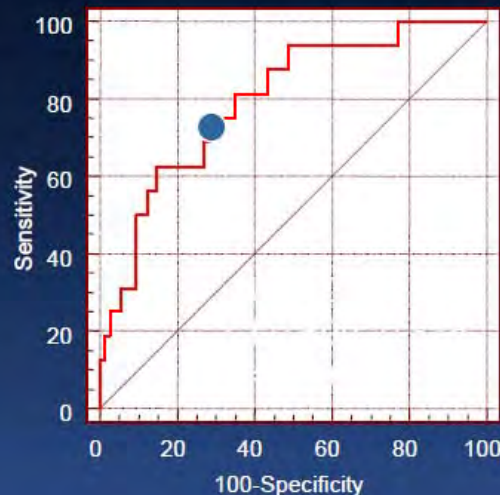
Sensitivity=94%

Specificity=68%

PPV=40%

NPV=98%

Plaque burden within SB ostium



Cut-off value;
51%

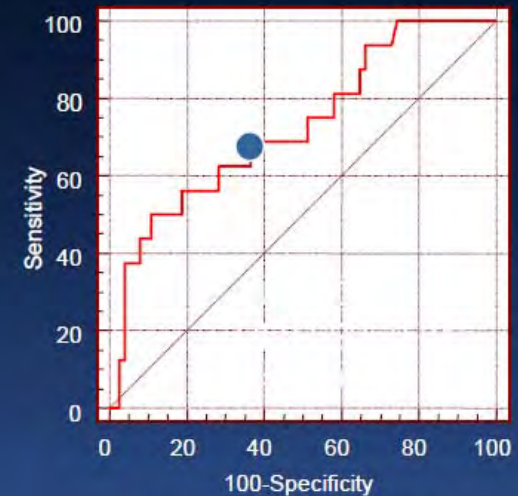
Sensitivity=75%

Specificity=71%

PPV=36%

NPV=93%

MLA within POC



Cut-off Value;
3.7mm²

Sensitivity=70%

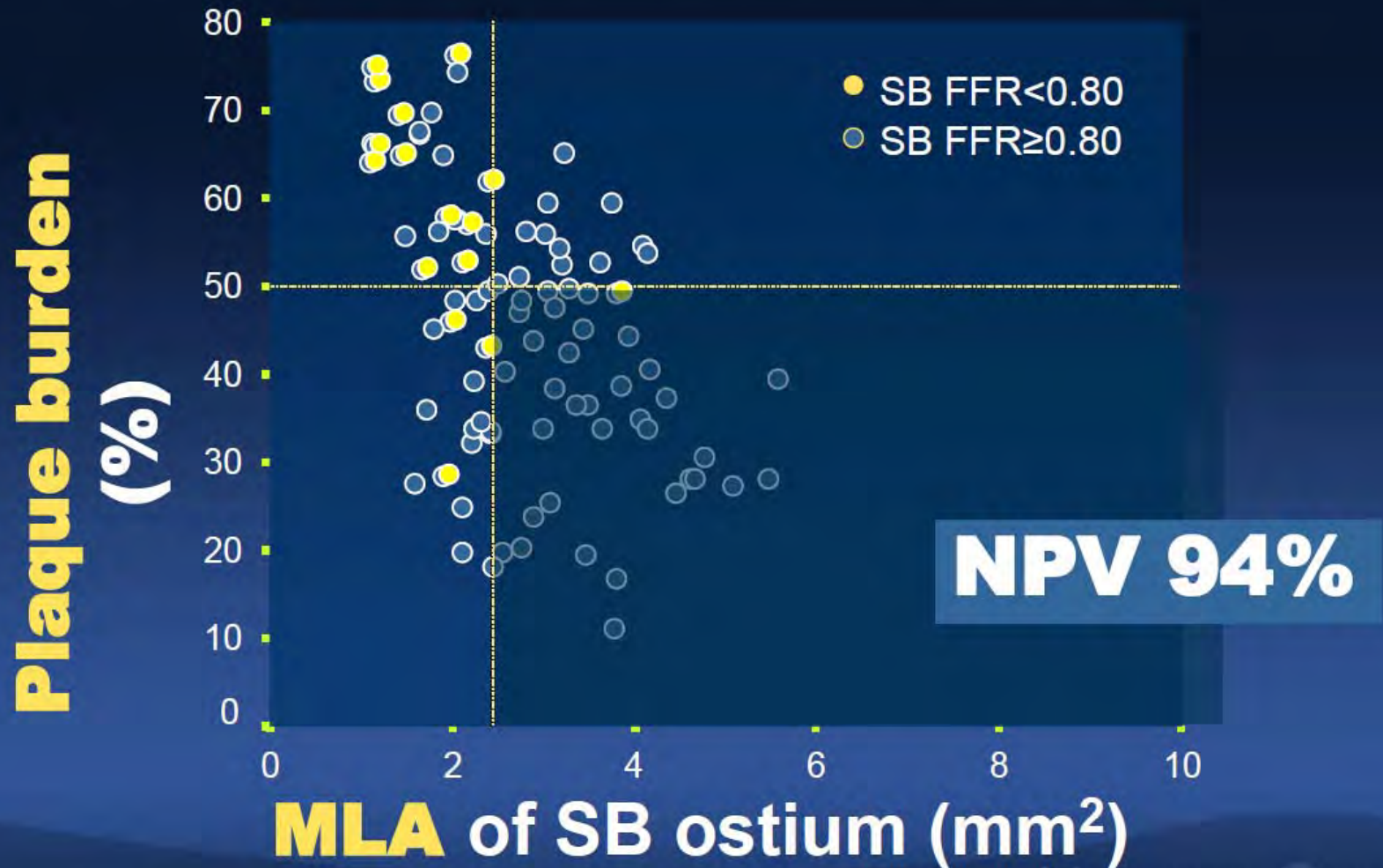
Specificity=64

PPV=50%

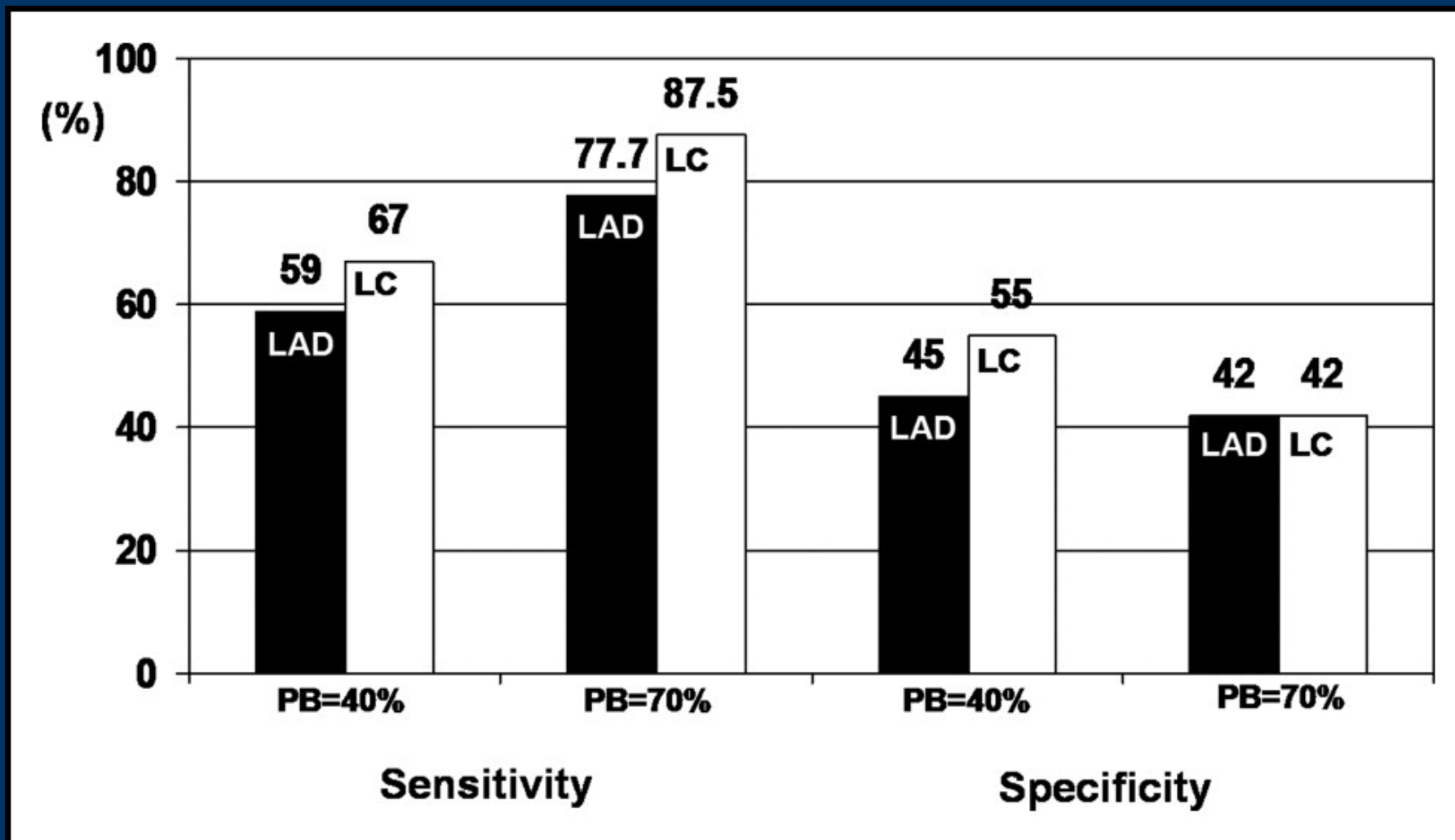
NPV=89%

Combining IVUS criteria

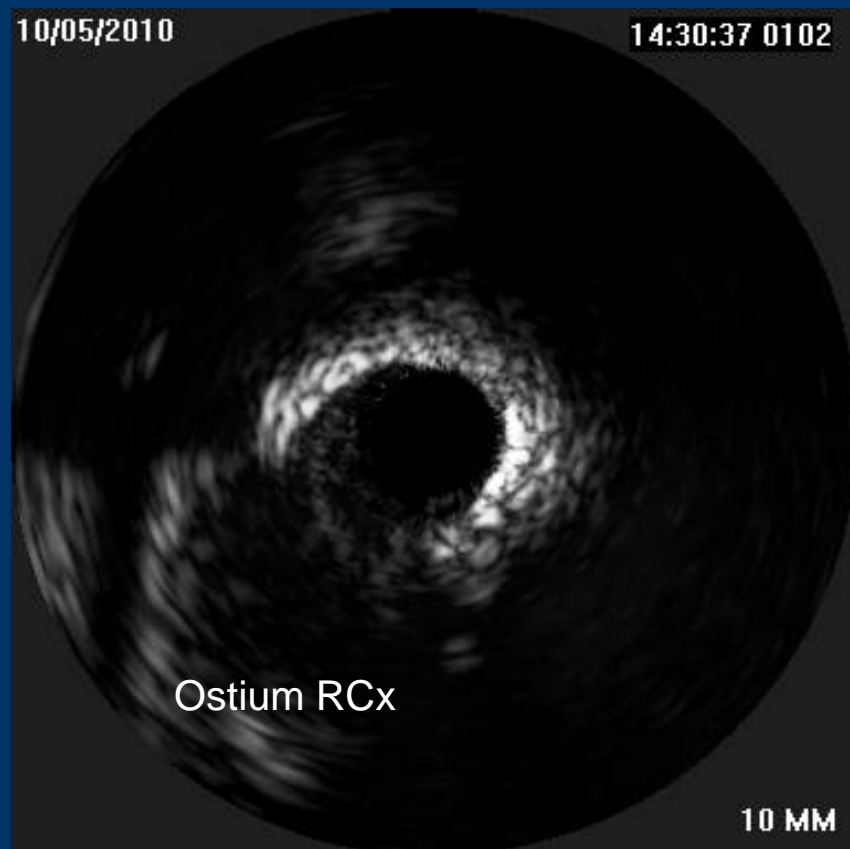
($MLA > 2.4 \text{ mm}^2$ and $PB < 50\%$ at SB ostium)



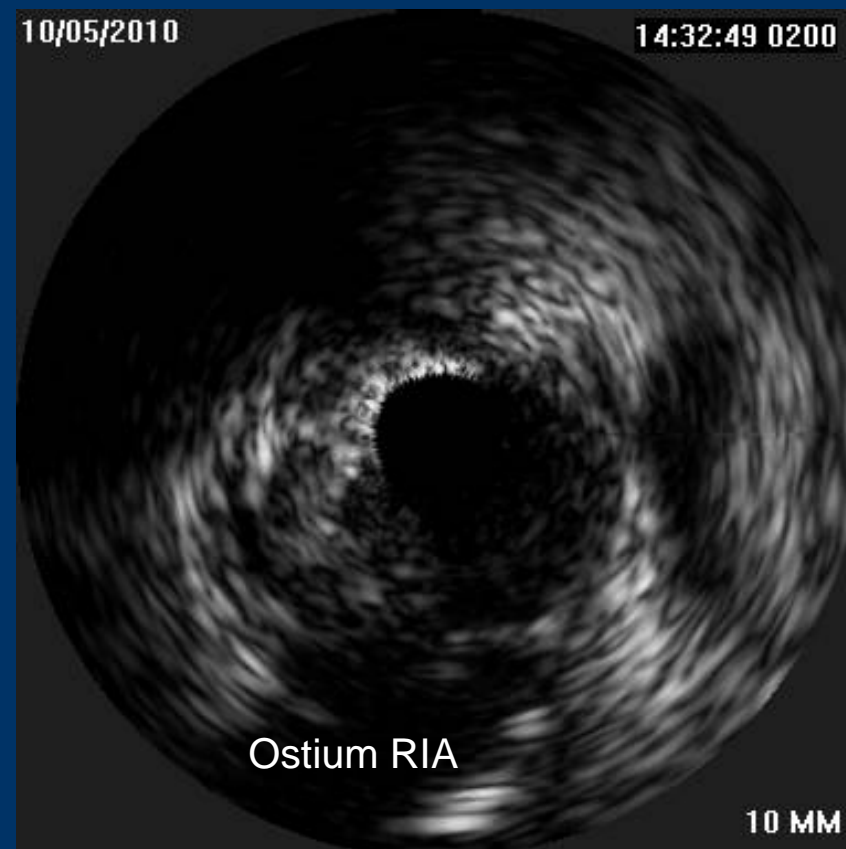
Hodnocení ostia RIA / RCX při pullbacku z druhé větve



Hodnocení ostia RCX



Pullback z RIA



Pullback z RCx

Postavení IVUS v katlabu 2011

- Hodnocení hemodynamické významnosti
- Hodnocení bifurkačních lézí
- **Wall shear stress**
- IVUS vedení intervencí
- Nejasné angiografické nálezy

Wall / endothelial shear stress

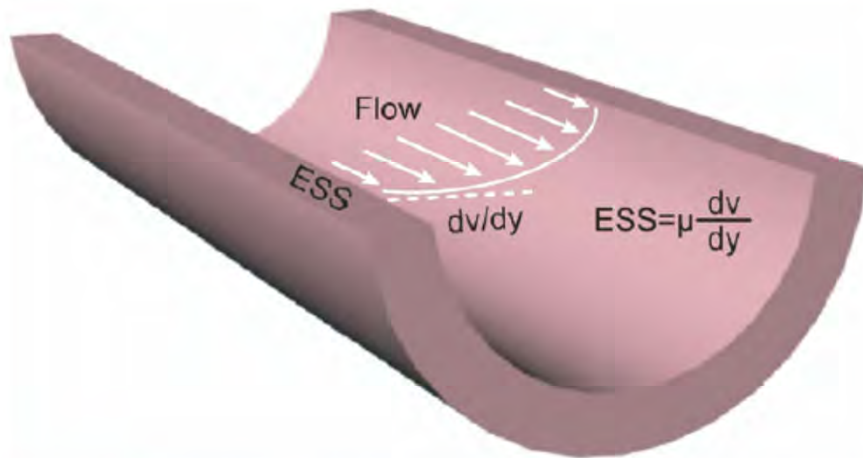
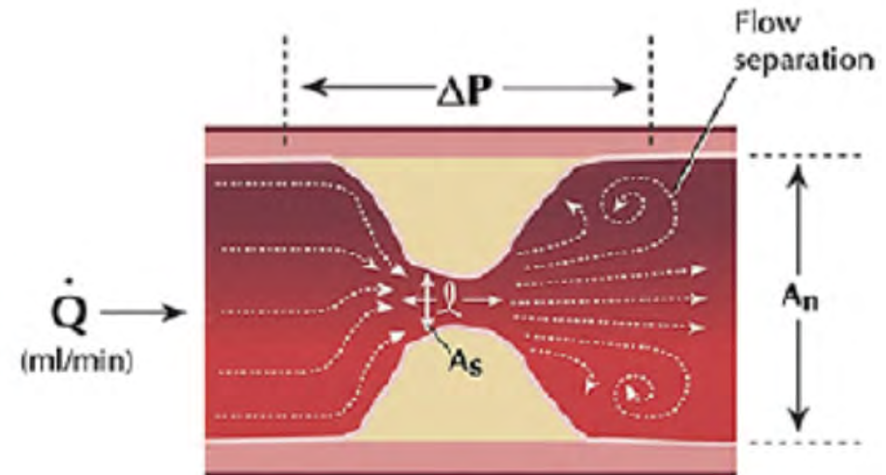


Figure 1 Definition of ESS

Endothelial shear stress (ESS) is proportional to the product of the blood viscosity (μ) and the spatial gradient of blood velocity at the wall (dv/dy).



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

Rychlé proudění –
vysoký shear stress



Pomalé proudění - nízký shear
stress – nánosy usazenin



Důsledky nízkého ESS na molekulární úrovni

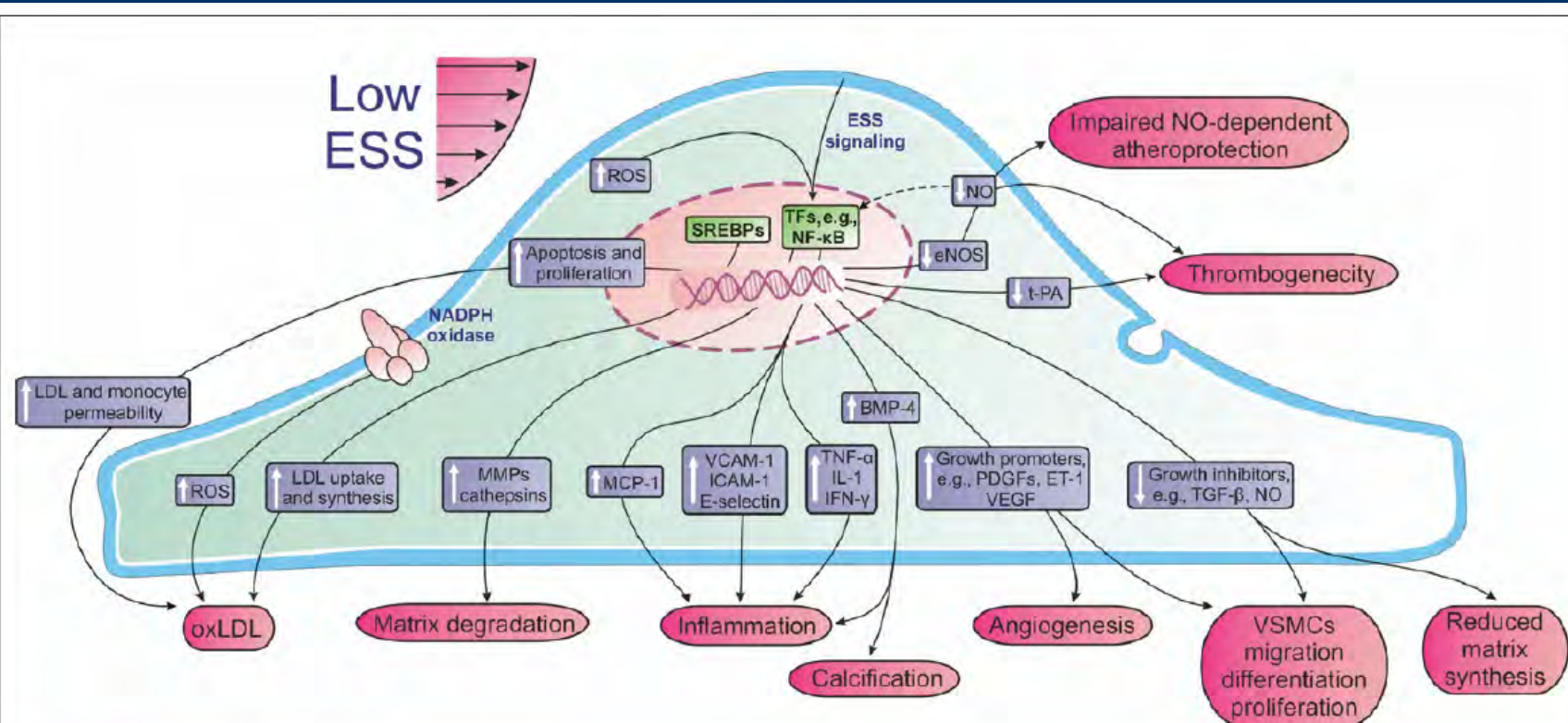


Figure 6 Role of Low ESS in Atherosclerosis

In arterial regions with disturbed laminar flow, low endothelial shear stress (ESS) shifts the endothelial function and structure toward an atherosclerotic phenotype, thereby promoting atherogenesis, atherosclerotic plaque formation and progression, and vascular remodeling. BMP = bone morphogenic protein; ET = endothelin; ICAM = intercellular adhesion molecule; IFN = interferon; IL = interleukin; LDL = low-density lipoprotein cholesterol; MCP = monocyte chemoattractant protein; MMP = matrix metalloproteinase; NO = nitric oxide; PDGF = platelet-derived growth factor; SREBP = sterol regulatory elements binding protein; TF = transcription factor; TGF = transforming growth factor; TNF = tumor necrosis factor; t-PA = tissue plasminogen activator; VCAM = vascular cell adhesion molecule; VEGF = vascular endothelial growth factor; VSMC = vascular smooth muscle cell; other abbreviations as in Figure 4.

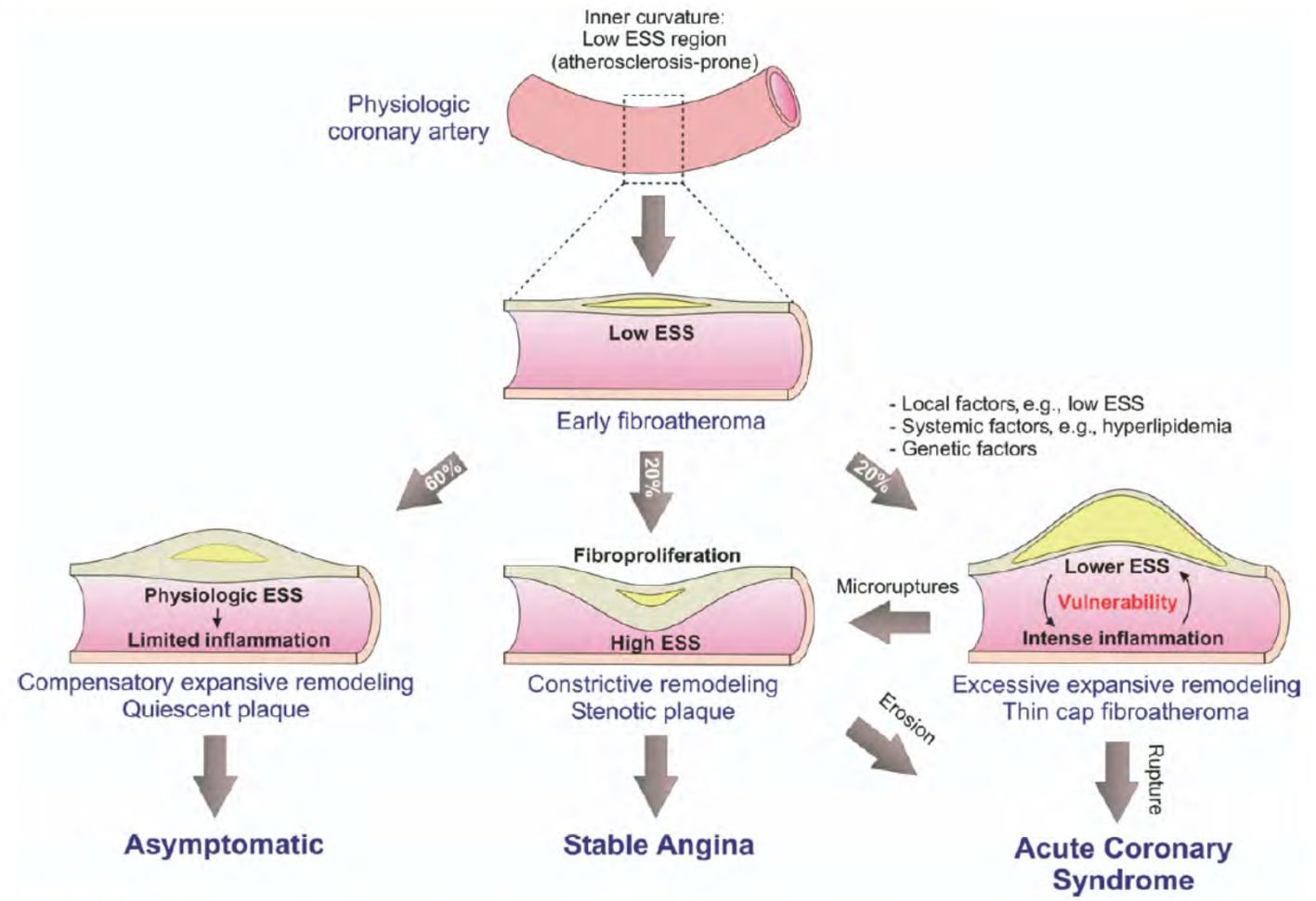
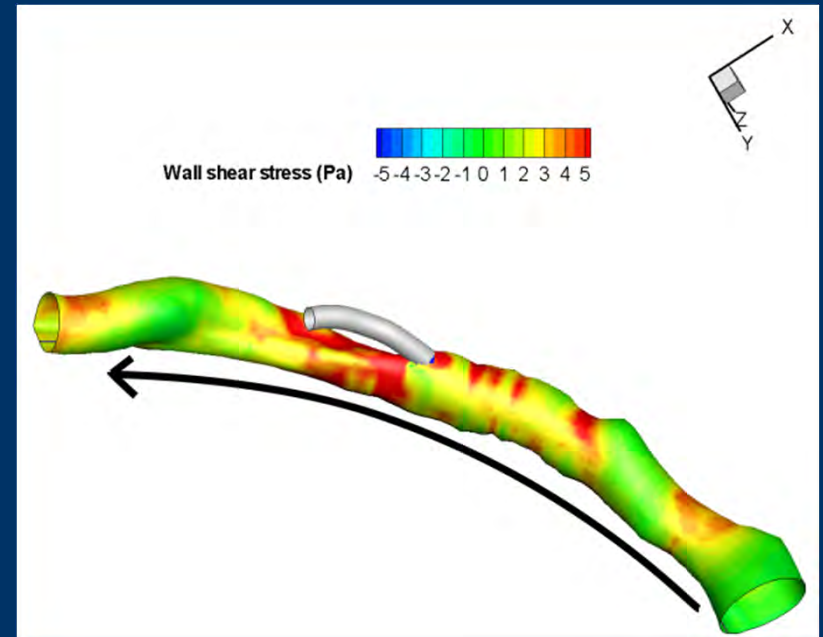
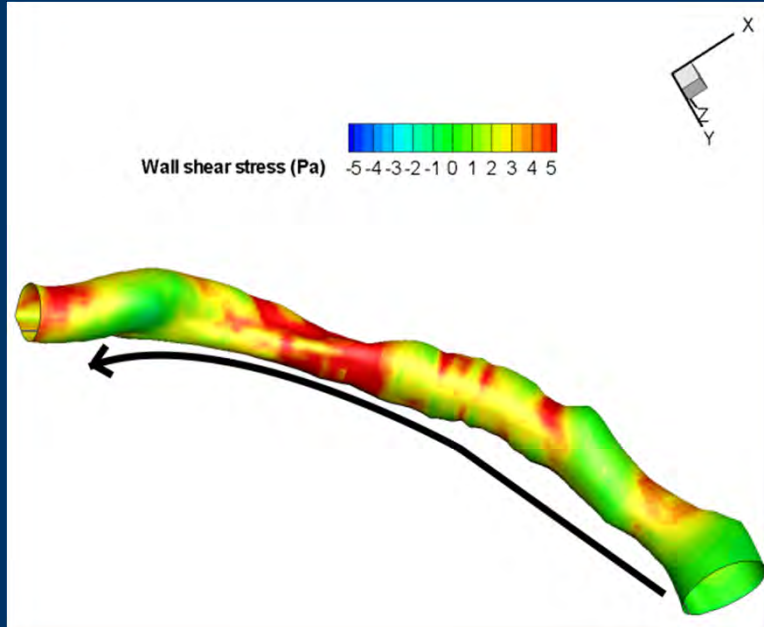
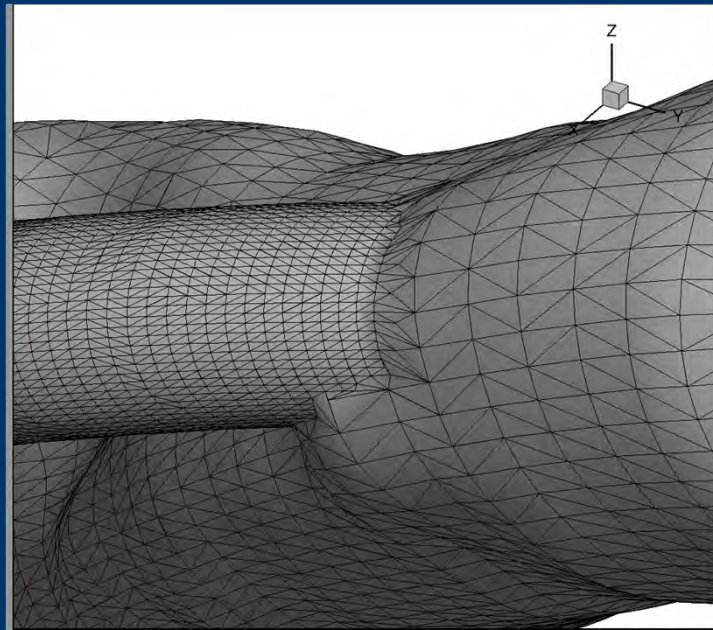
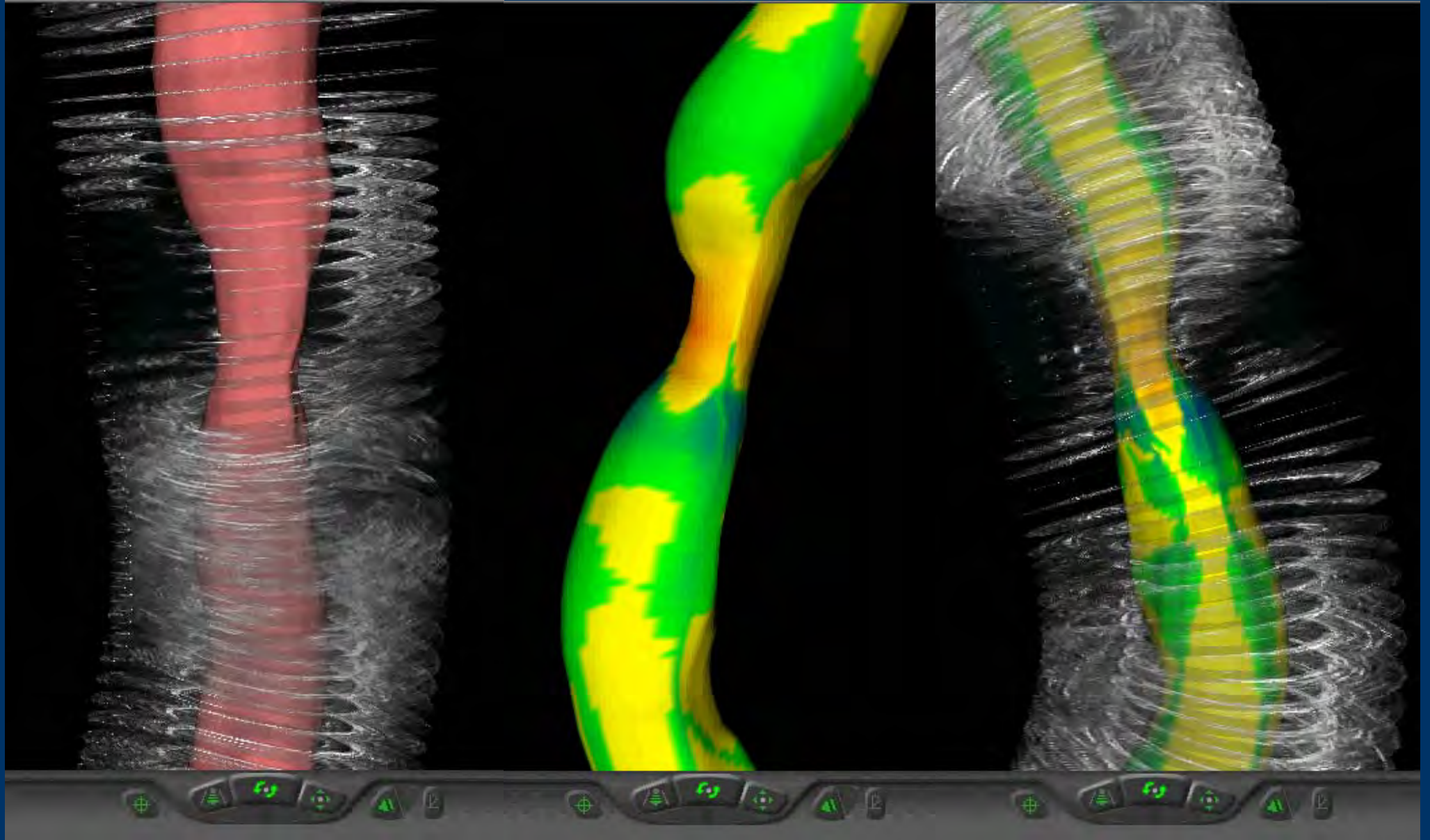


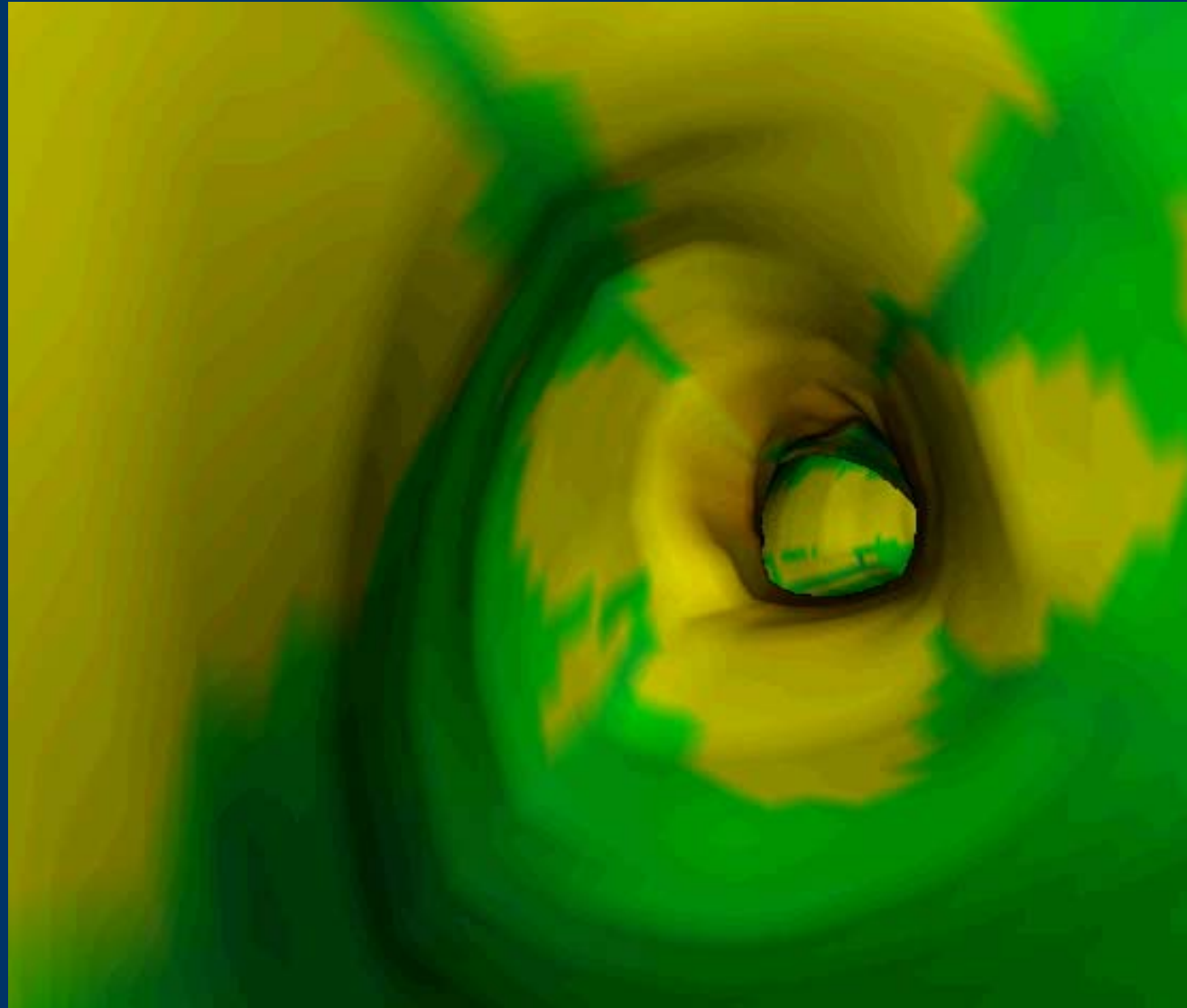
Figure 7 Proposed Natural History of Coronary Atherosclerosis

The initiating process of atherosclerosis in an atherosclerosis-prone host is a low endothelial shear stress (ESS) environment, leading to the formation of an early fibroatheroma, which might be diffuse. The vascular response to that early fibroatheroma likely determines the nature of the subsequent natural history of that plaque. If there is local compensatory expansive remodeling, then the local ESS is normalized, the hemodynamic stimulus for further plaque progression is resolved, and the early lesion evolves to a quiescent plaque with limited inflammation. However, in the presence of certain local, systemic, and genetic factors, the local vascular wall might undergo excessive expansive remodeling. In this context the local low ESS environment persists, promoting further plaque progression and vessel expansion. A self-perpetuating vicious cycle is established among local low ESS, excessive expansive remodeling, and plaque inflammation, transforming the early fibroatheroma to a thin cap fibroatheroma. The stenotic plaques might either evolve with a phenotype promoting fibroproliferation consistently throughout their natural history course or represent an end-stage of scarring in the setting of prior inflamed thin cap fibroatheroma through repetitive microruptures and healing. Also, the stenotic plaques might infrequently undergo local erosion or develop calcified nodules and lead to local thrombus formation and manifestation of an acute coronary syndrome. The percentages reported in the figure are based on intravascular ultrasound studies (23,110,111).





Virtuální endoskopie



Postavení IVUS v katlabu 2011

- Hodnocení hemodynamické významnosti
- Hodnocení bifurkačních lézí
- Wall shear stress
- **IVUS vedení intervencí**
- Nejasné angiografické nálezy

IVUS vs. angio vedená implantace stentů

IVUS lepší

- AVID, (*Circulation* 1996;94:1538A)
 - ↓TVR (8,4% vs. 12,4%)
- CRUISE (*Circulation* 2000;102:523)
 - ↓TVR (8,5% vs. 15,3%)
- TULIP (*Circulation* 2003;107: 62)
 - ↓ restenóza (23% vs. 46%)
- MUSIC (*Eur Heart J* 1998;19:1214)
 - restenóza 7%, TVR 4%
- Colombo (*JACC* 2001;38:1427-33)
 - ↓ restenóza (25% vs 39%)
- Blasiny (*Cath Cardiovasc Diagn* 1998;44:380)
 - ↓ restenóza (20,9% vs. 29,9%)
- Roy (*Eur Heart J* 2008;29:1851)
 - ↓ in stent trombóza (0,5% vs 1,4%/ měsíc, 0,7% vs. 2,0% / rok)
 - ↓ TLR /30 dnů (2,3% vs. 4,4%)
 - ↓ úmrtí /měsíc (1,7% vs 3,3%)

Bez rozdílu

- RESIST (*JACC* 1998;32:320-8)
 - restenóza 22,5% vs. 28,8%
- OPTICUS (*Circulation* 2000;104:1343)
 - restenóza 24,5% vs. 22,8%
- Choi (*Am Heart J* 2001;142:112)
 - TVR 11% vs. 19%, MACE 12% vs. 19%
- PRESTO (*Am Heart J* 2004;148:501)
 - TVR 13,8% IVUS, 12,2% angio, ns

➔ **nejdůležitějším prediktorem in stent restenózy a TVR je MSA**

➔ **IVUS vedený stenting dlouhých lézí snižuje i přes větší počet stentů a implantaci delších stentů restenózu, TVR i MACE**

➔ **IVUS vedený stenting snižuje výskyt IST**

IVUS vedení implantace stentů a IST

1768
pacientů

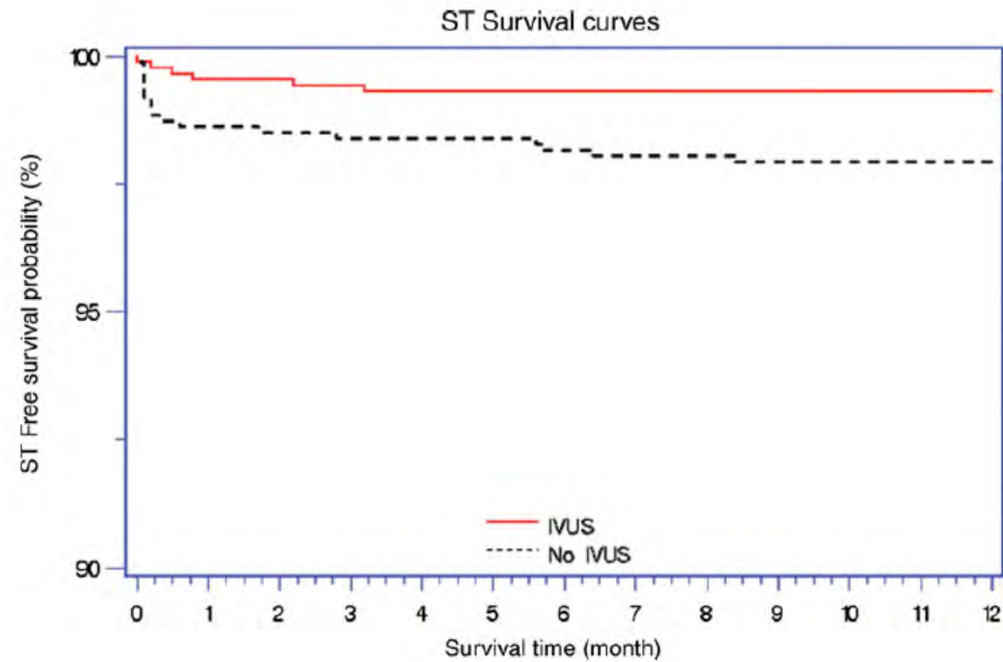
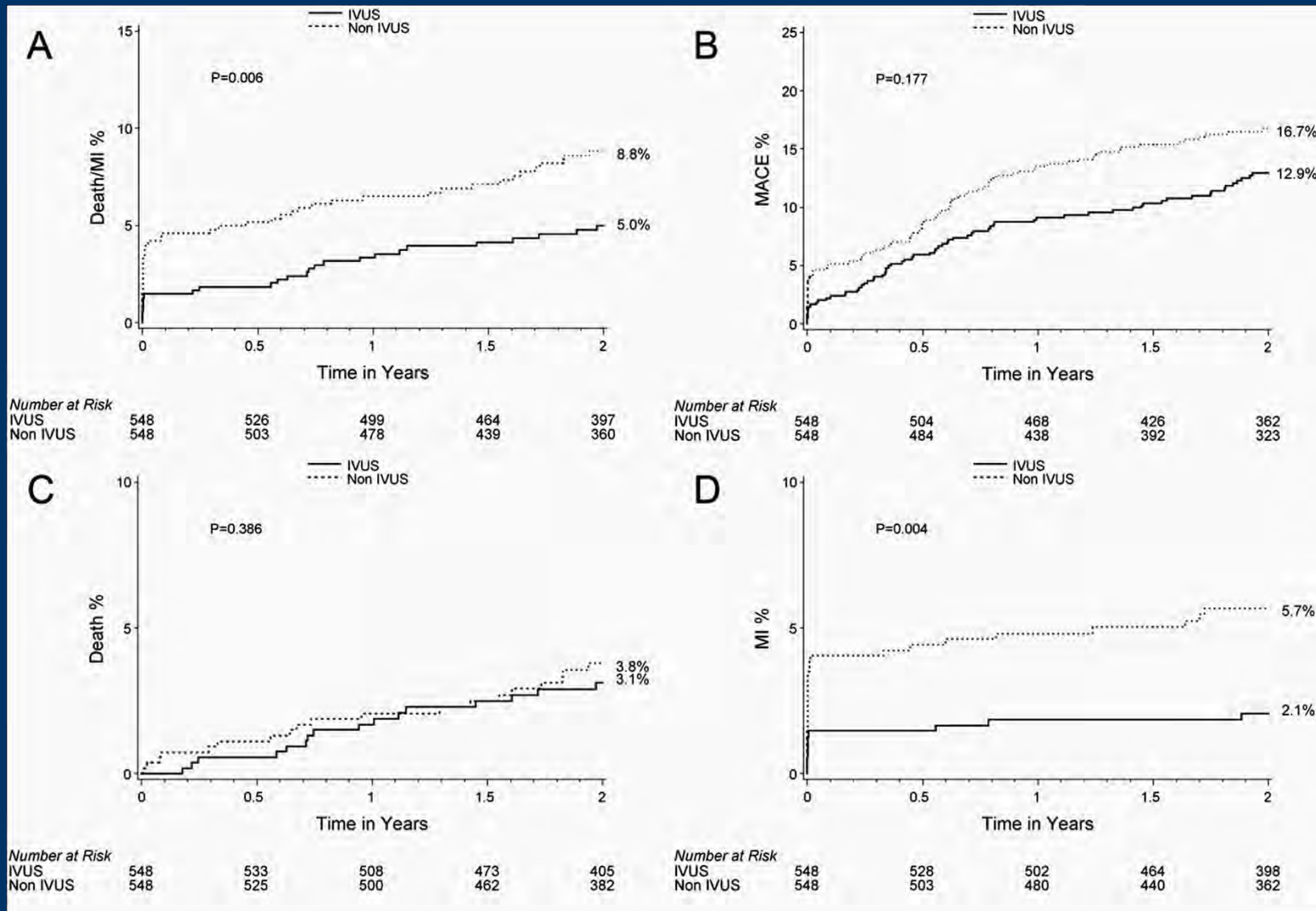
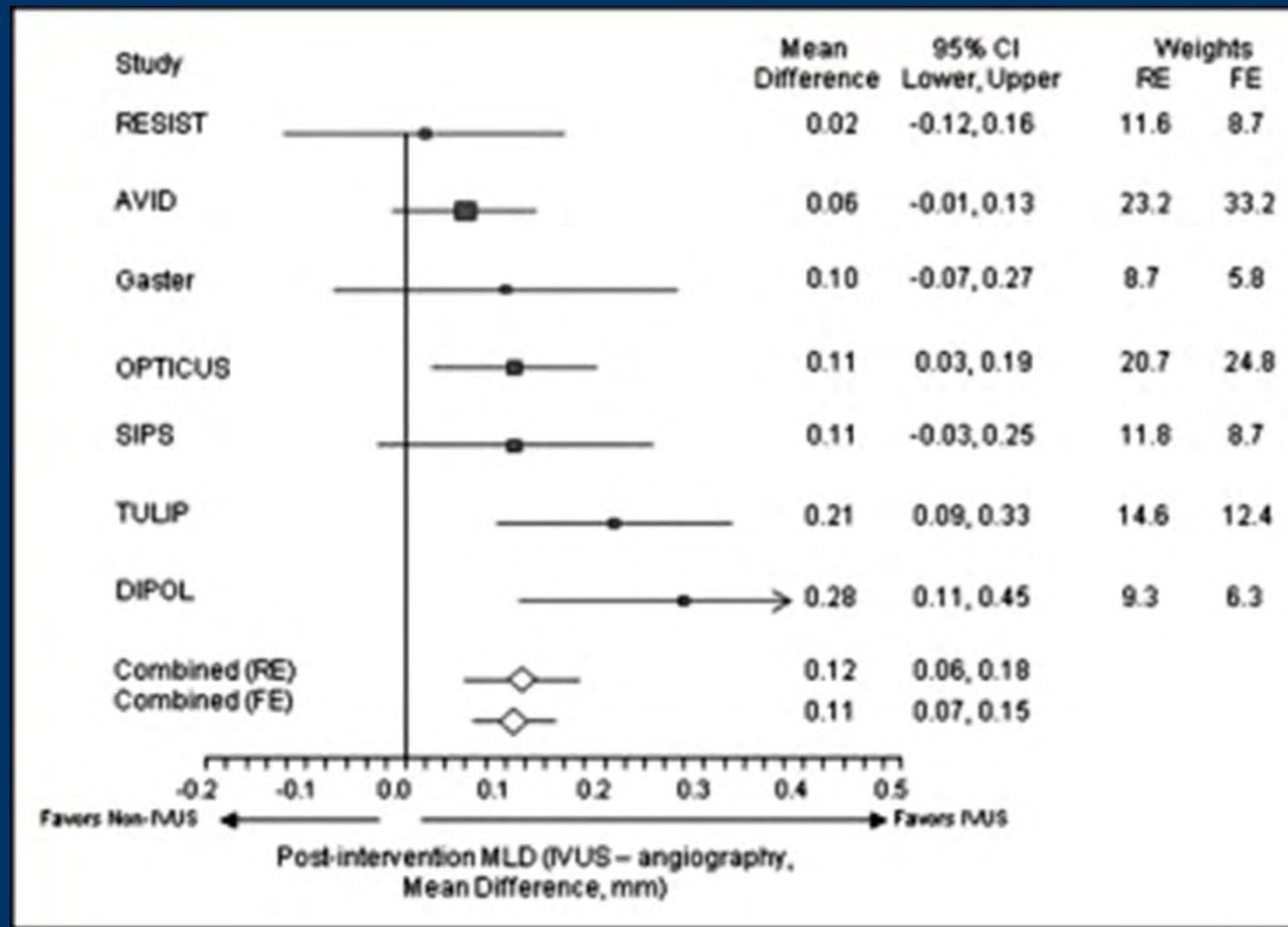


Figure 1 Kaplan–Meier curves illustrating freedom from stent thrombosis in IVUS and no IVUS groups over 12 months ($P = 0.013$).

Angio (873 pac.) vs. IVUS (631) guided PCI s implantací SES



Meta analýza angio vs. IVUS guided PCI



IVUS guiding:

- ↓ 6-měsíční angiografická restenóza
- ↓ 12-měsíční revaskularizace a MACE
- žádný efekt na mortalitu a MI

Angio (3744 pac.) vs. IVUS (4627 pac) guiding v reálném světě – 1998-2006, FU 3 roky

- 3 leté přežití v celé skupině
 - 93,6% vs. 96,4%, $p < 0,001$
- 3 leté přežití u DES
 - IVUS je spojen s lepším přežitím HR 0,46, $p < 0,001$
- 3 leté přežití u BMS
 - Bez rozdílu
- Příčina snížené mortality v IVUS skupině není jasná:
 - Výskyt IM, TVR a IST byl stejný v obou skupinách

IVUS predictors of inadequate ST resolution in STEMI

Table 3. IVUS Findings

	Absent STR (n=55)	Partial STR (n=101)	Complete STR (n=150)	P value
Proximal reference				
EEM CSA, mm ²	15.1±5.3	17.0±5.1	15.4±5.4	0.02
Lumen CSA, mm ²	8.9±3.9	10.1±3.7	8.9±3.1	0.02
Lesion site				
EEM CSA, mm ²	17.8±5.6	16.4±5.4	15.8±4.8	0.048
Plaque & media CSA, mm ²	16.0±5.5	14.4±5.2	13.8±4.7	0.02
Plaque burden, %	89±4	87±5	86±4	<0.001
Remodeling Index	1.22±0.34	0.98±0.18	1.05±0.24	<0.001
Post minimum stent CSA, mm ²	7.3±2.4	7.0±2.2	6.3±2.3	<0.001
Percentage stent expansion	95±21	83±19	80±17	<0.001
Plaque morphology				
				0.02
Soft, n (%)	14 (25)	26 (25)	38 (25)	
Fibrous, n (%)	16 (29)	26 (25)	33 (22)	
Mixed, n (%)	25 (46)	49 (48)	65 (44)	
Calcified, n (%)	0 (0)	0 (0)	14 (9)	
Plaque rupture, n (%)	20 (36)	29 (29)	44 (29)	0.6
Dissection, n (%)	7 (13)	18 (18)	23 (15)	0.7
Ultrasound attenuation <180°, n (%)	33 (60)	42 (42)	39 (26)	<0.001
Lipid pool-like image, n (%)	26 (47)	37 (37)	60 (40)	0.4
Deep calcium, n (%)	43 (78)	67 (68)	72 (48)	<0.001
Superficial calcium, n (%)	16 (29)	43 (43)	63 (42)	0.2

Data are presented as mean ± SD or n (%).

IVUS, intravascular ultrasound; CSA, cross-sectional area; EEM, external elastic membrane; STR, ST-segment resolution.

Rutinní IVUS vedení intervencí u STEMI

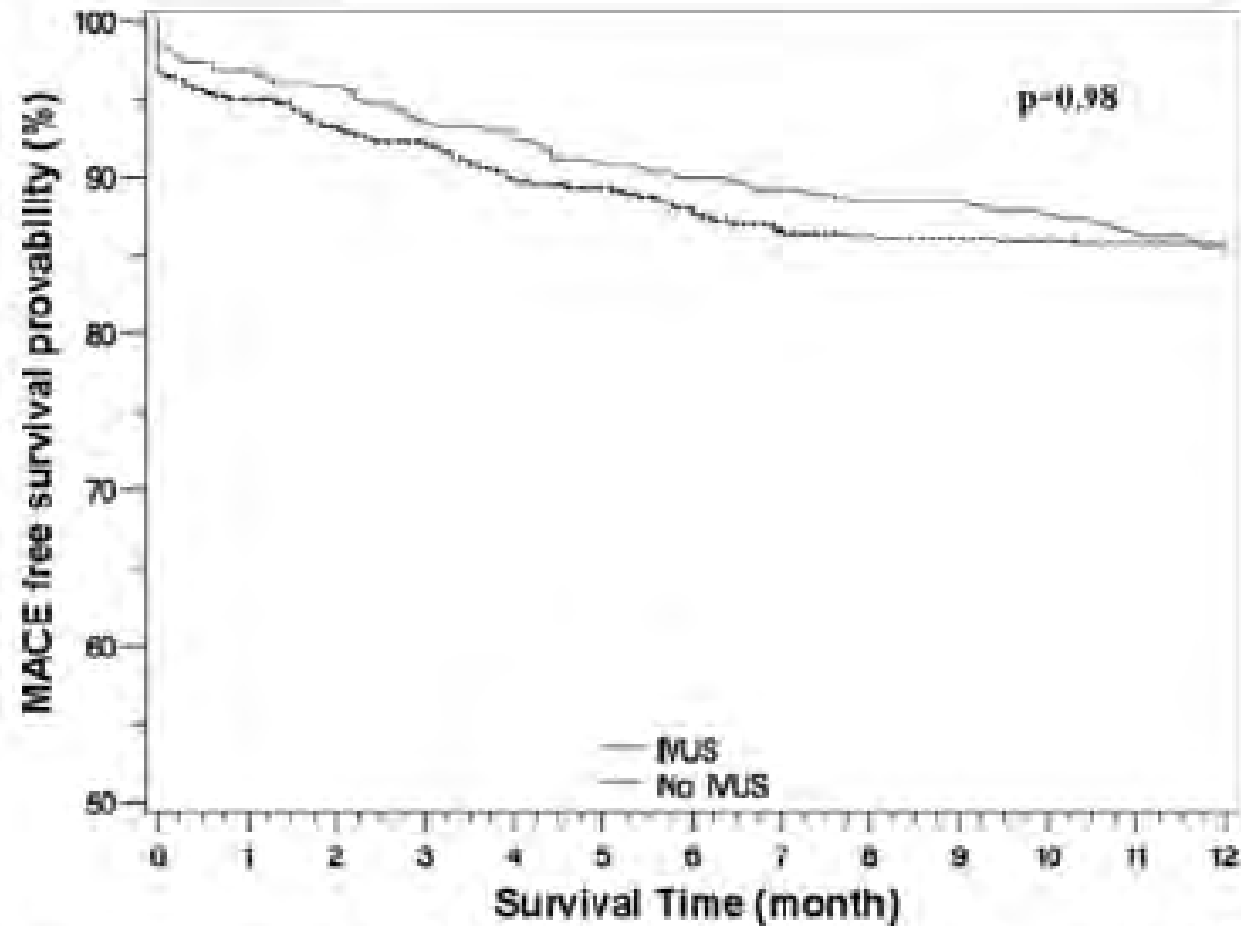


Fig. 1. Kaplan-Meier curves illustrating freedom from MACE over 12 months ($P = 0.98$).

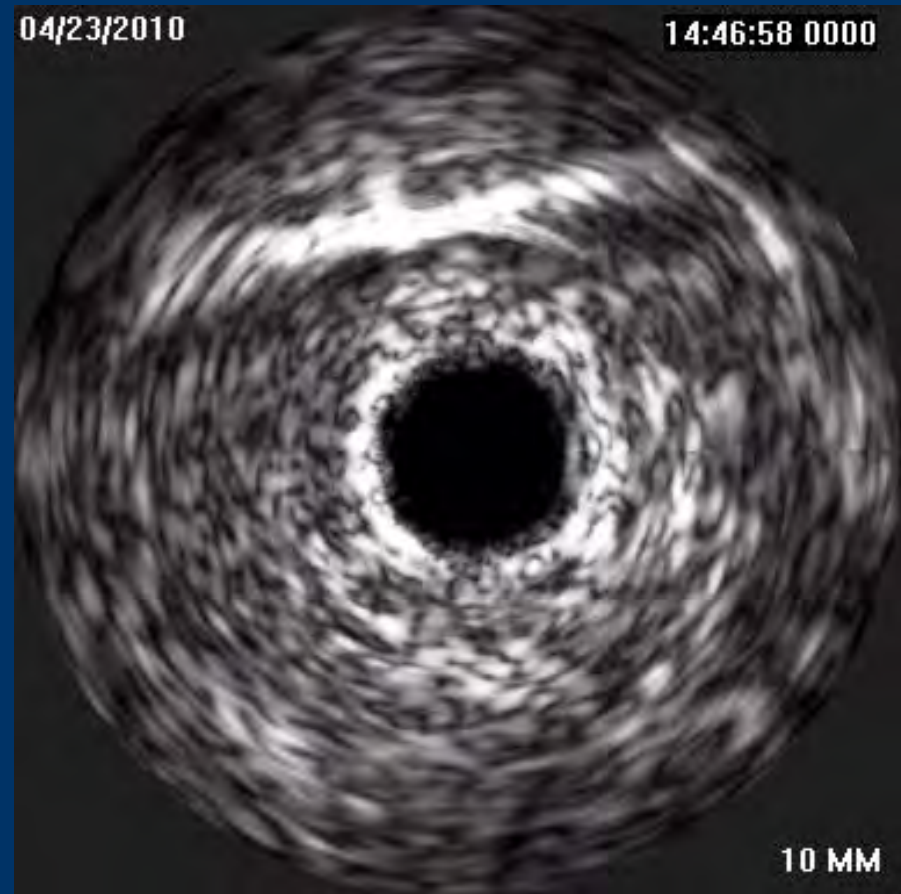
Postavení IVUS v katlabu 2011

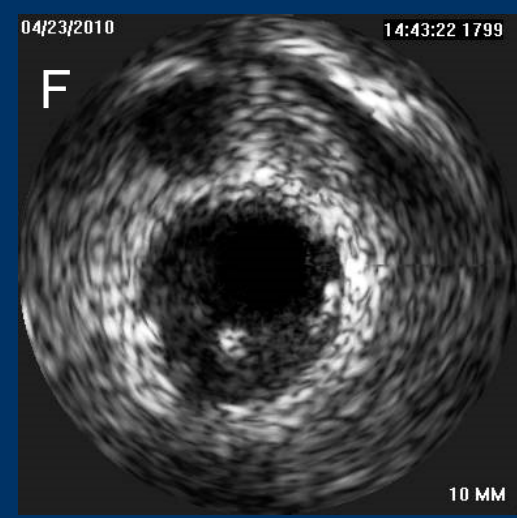
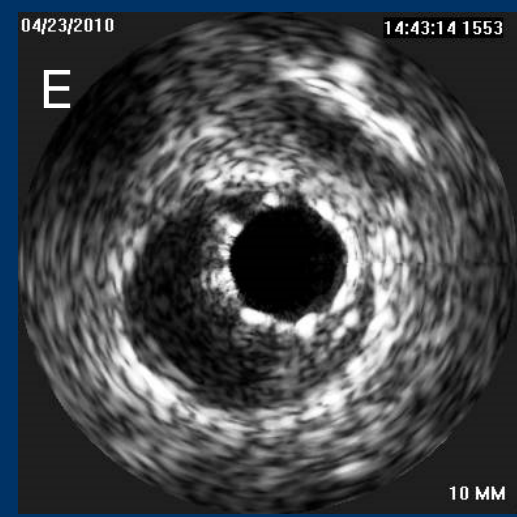
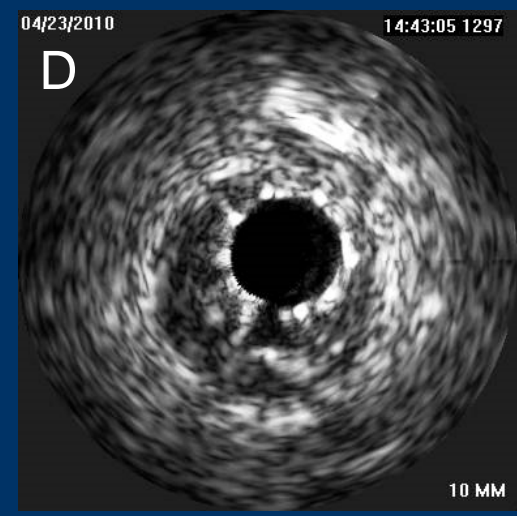
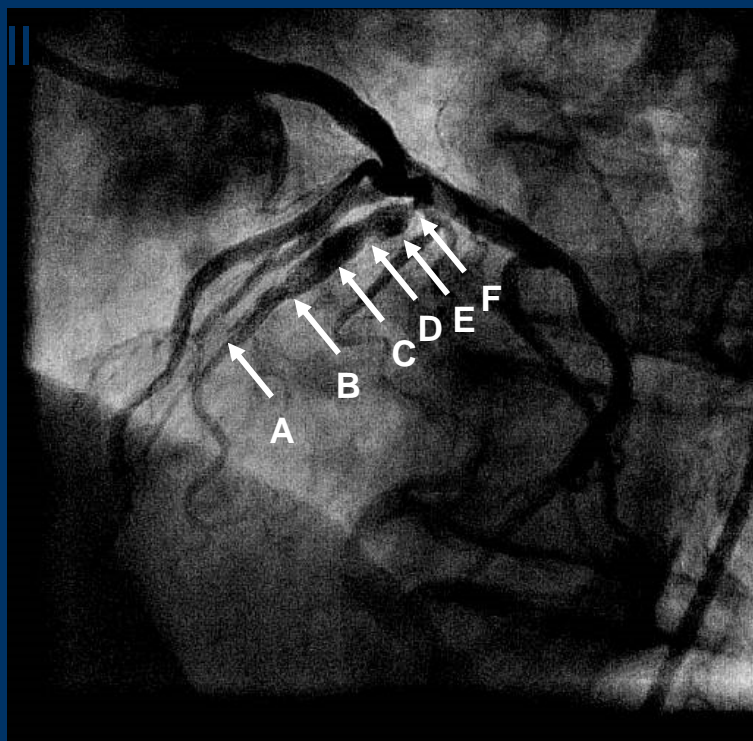
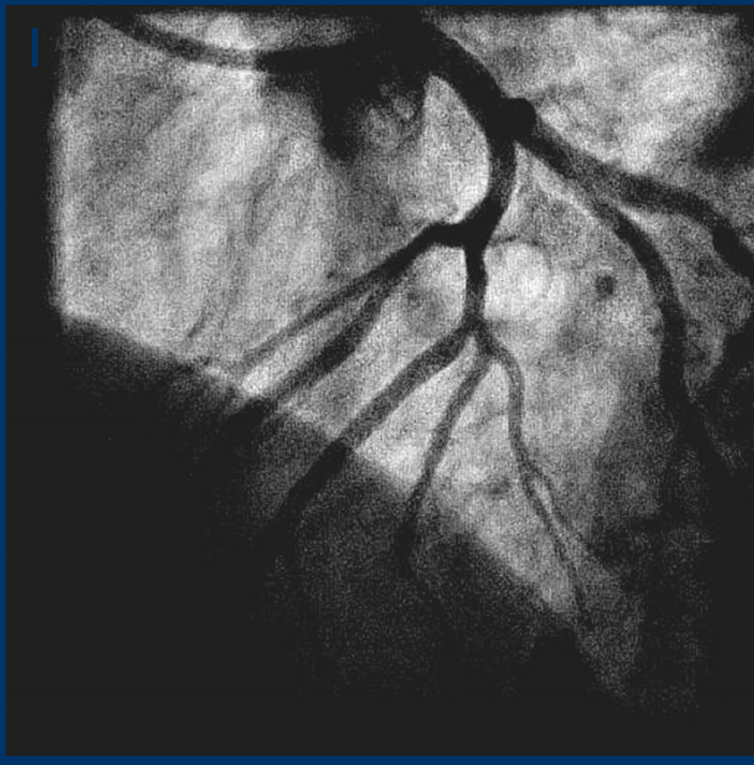
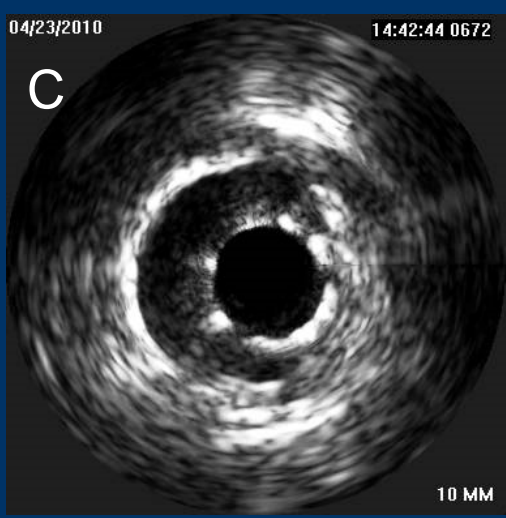
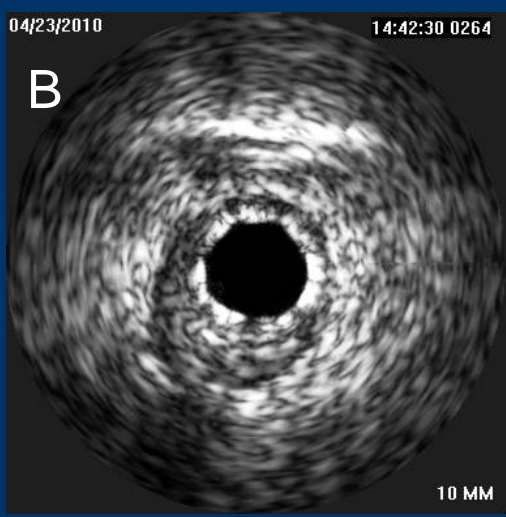
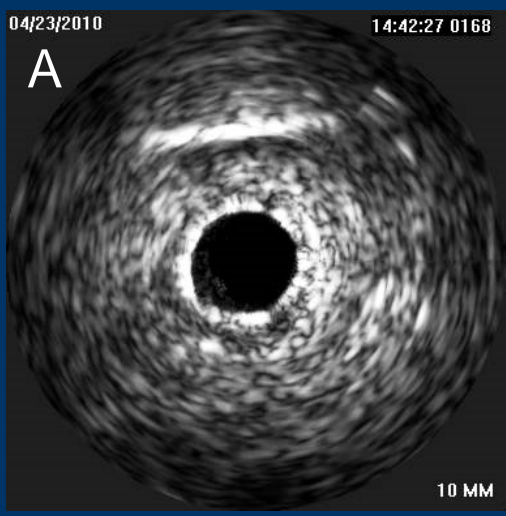
- Hodnocení hemodynamické významnosti
- Hodnocení bifurkačních lézí
- Wall shear stress
- IVUS vedení intervencí
- **Nejasné angiografické nálezy**

Pozdní malapozice ve stentu po predilataci léze DEB

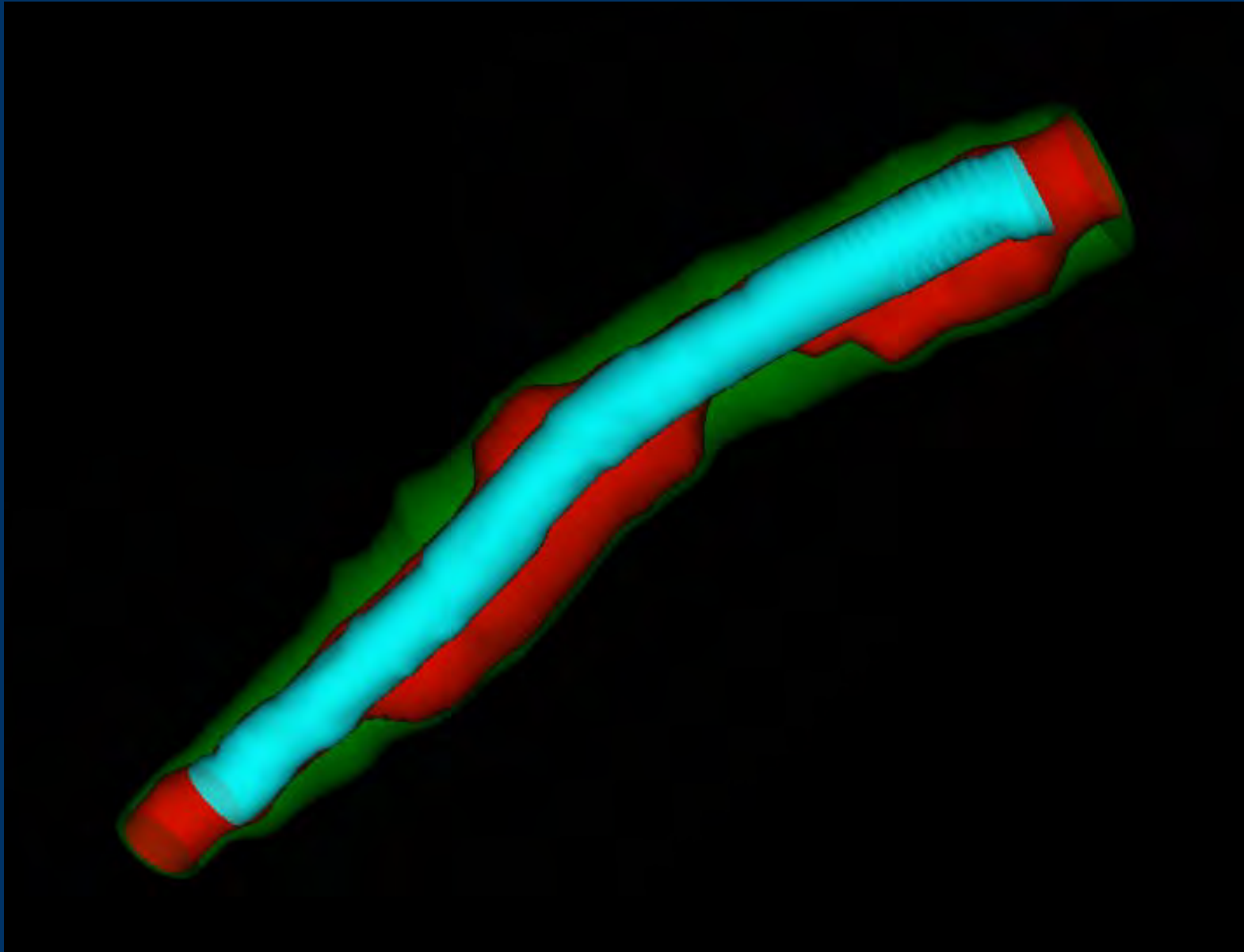


Pozdní malapozice ve stentu po predilataci léze DEB

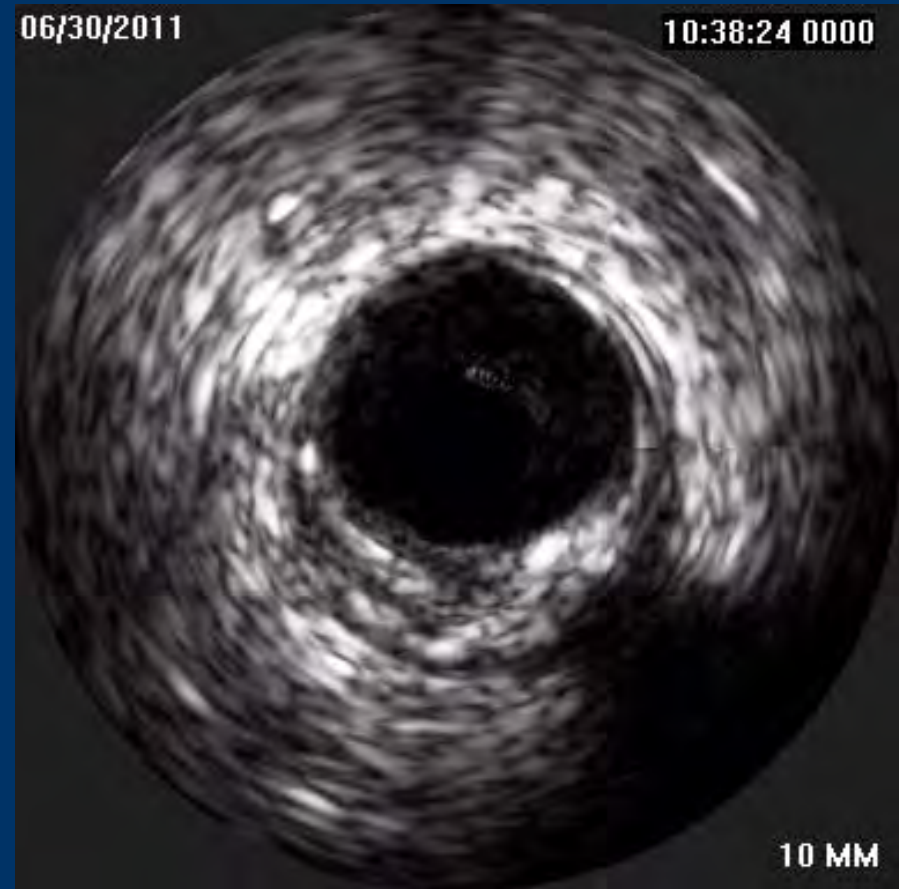
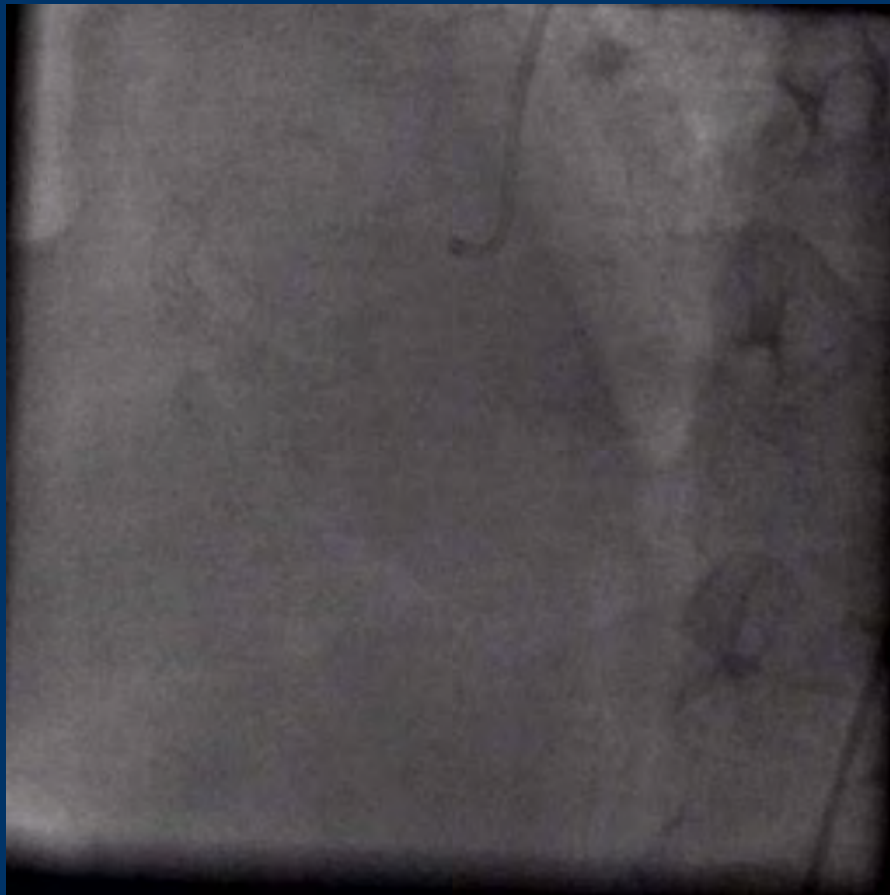


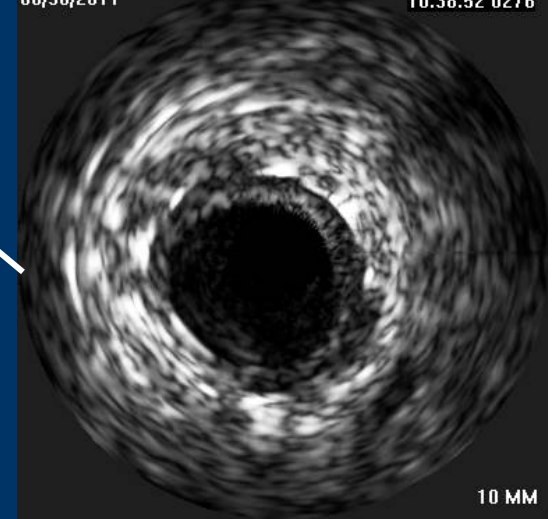
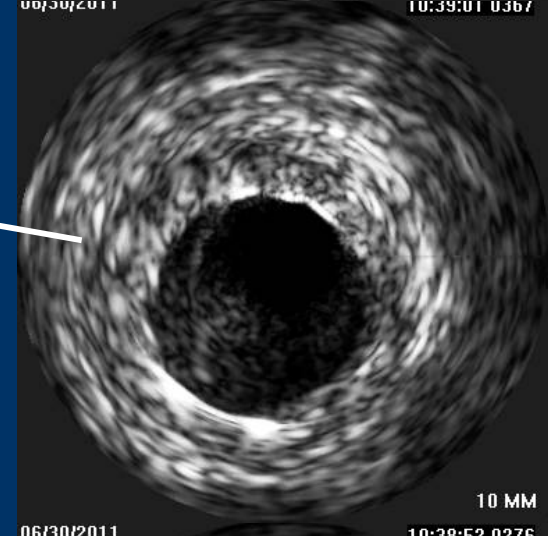
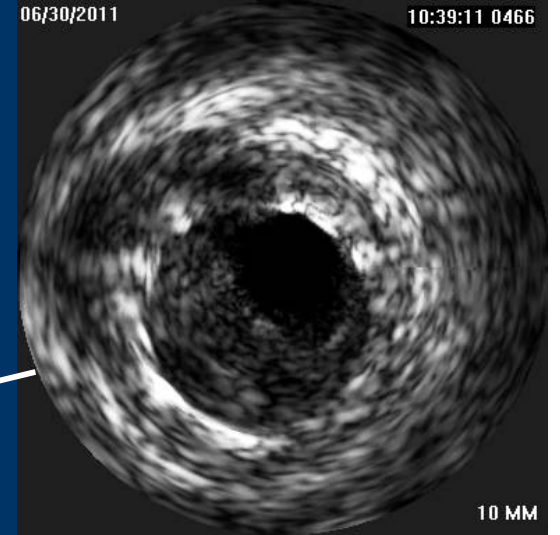
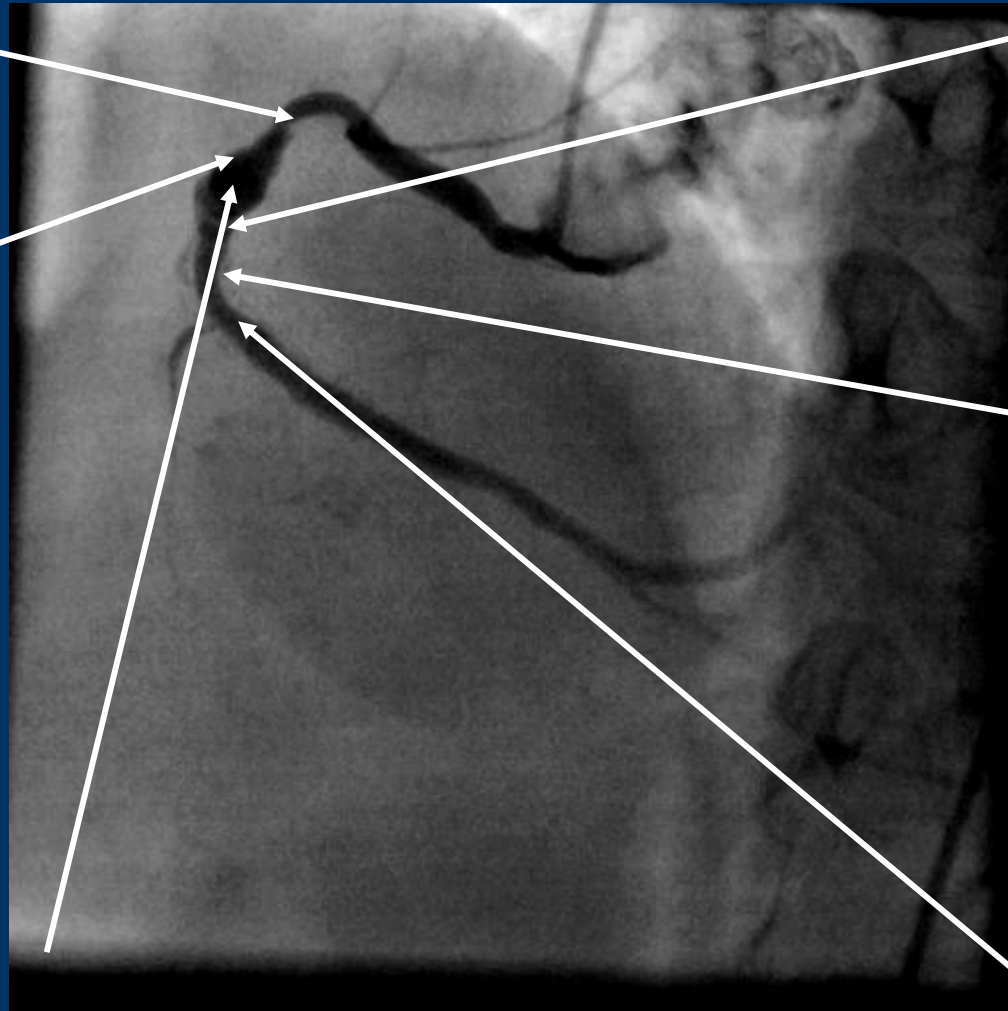
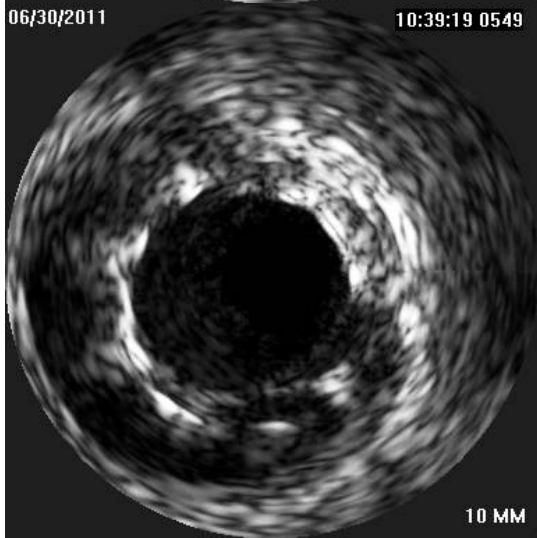
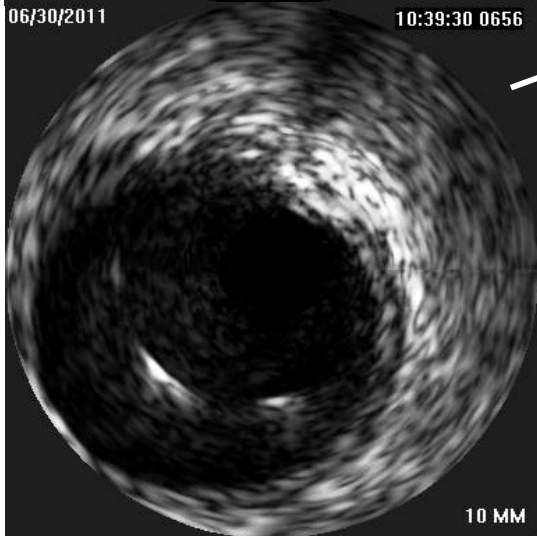
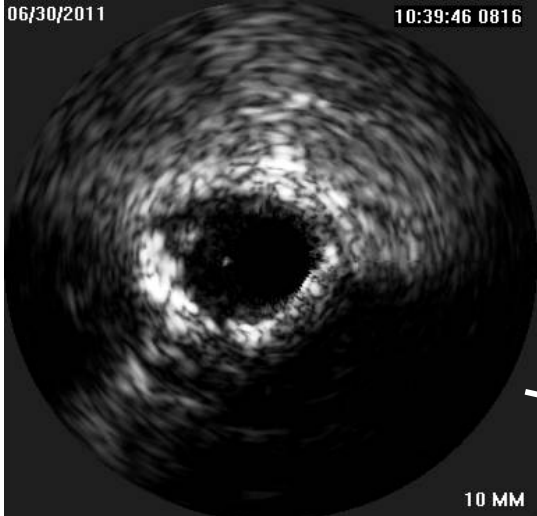


Pozdní malapozice ve stentu po predilataci léze DEB



Pozdní aneurysma ve stentu s trombem





10 MM

10 MM

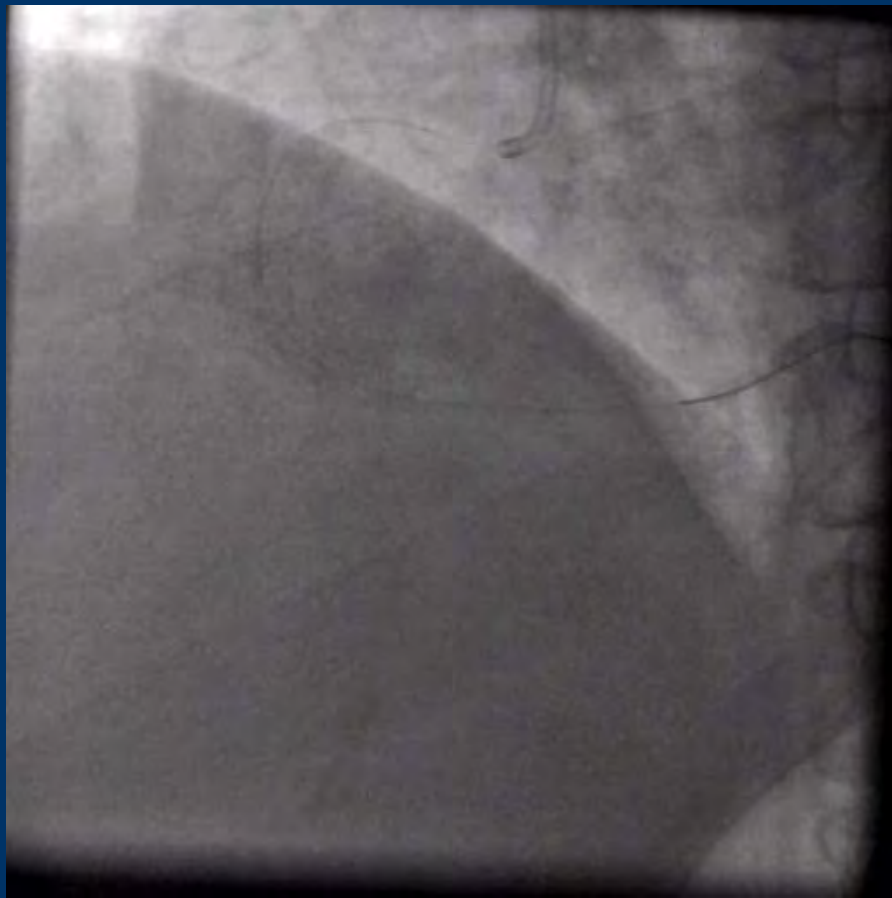
10 MM

10 MM

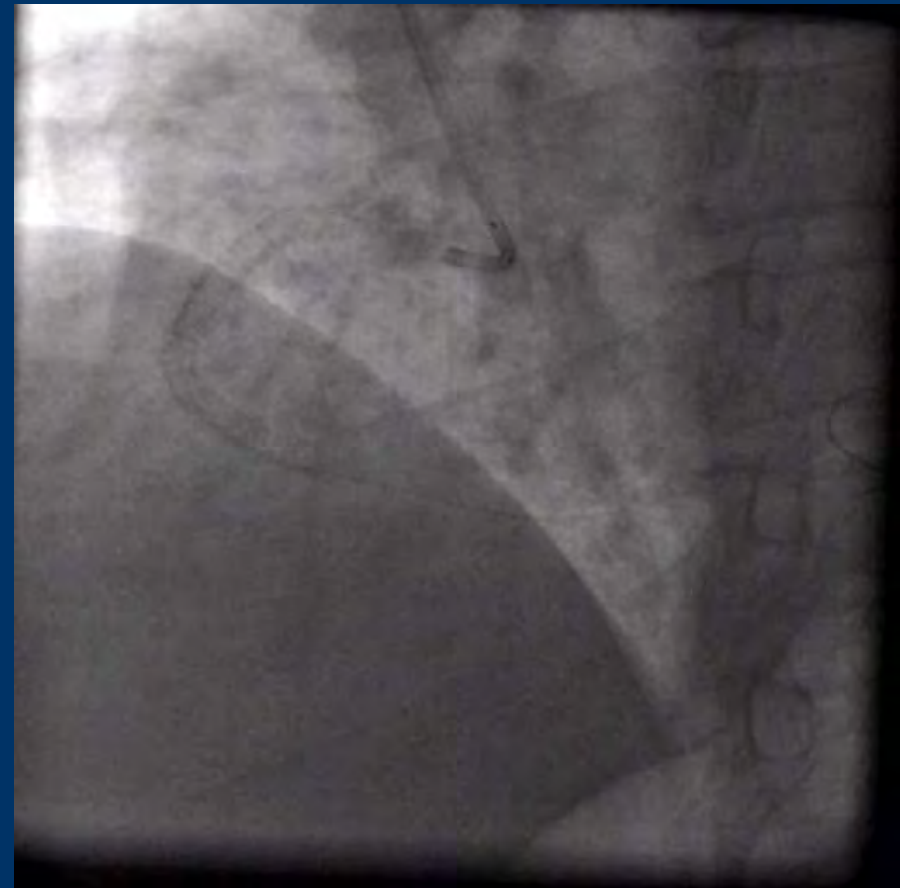
10 MM

10 MM

Pozdní aneurysma ve stentu s trombem - léčba

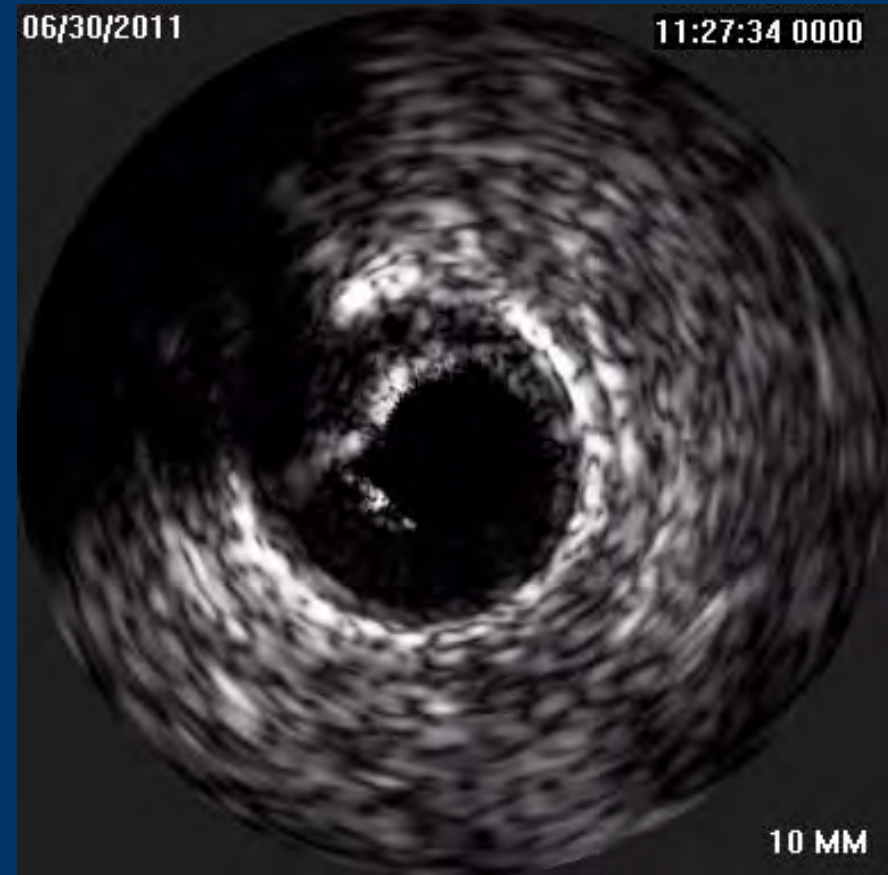
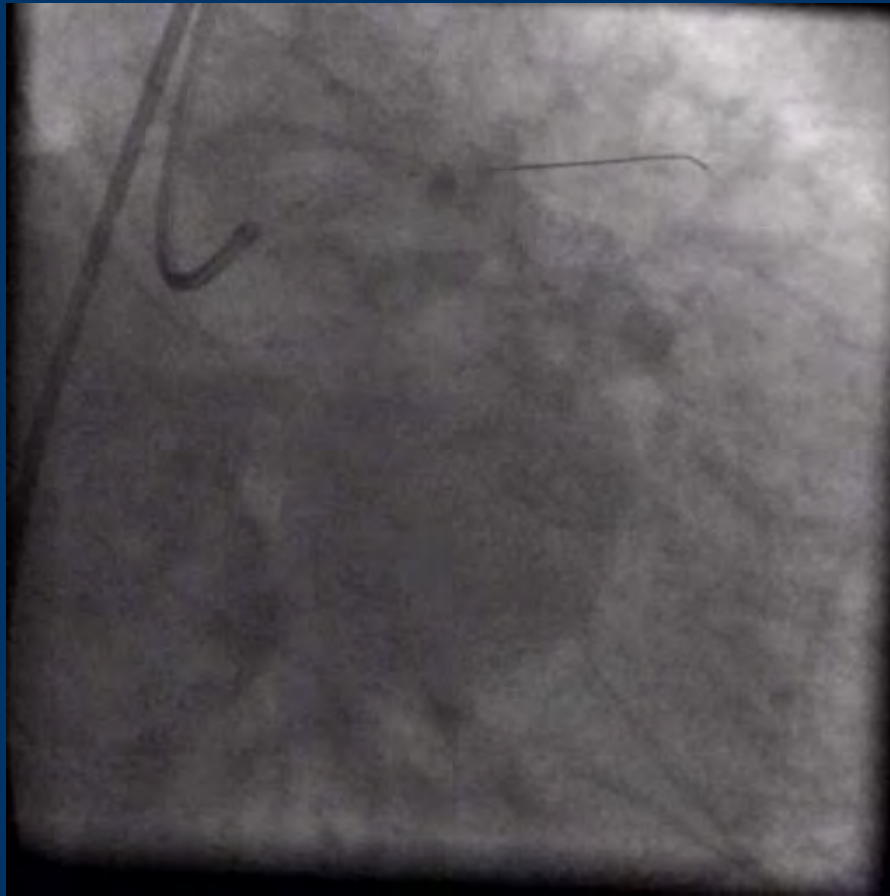


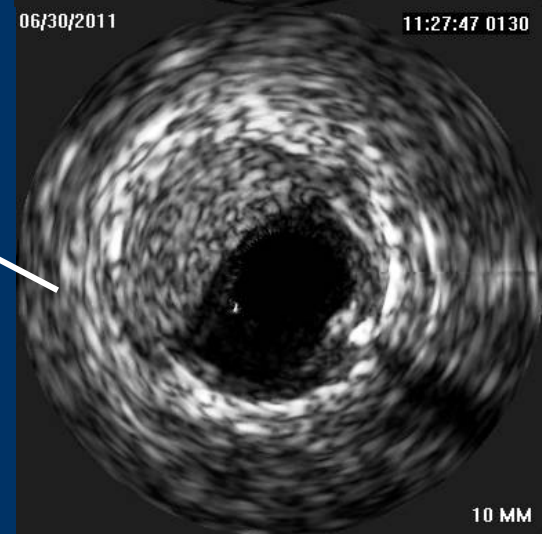
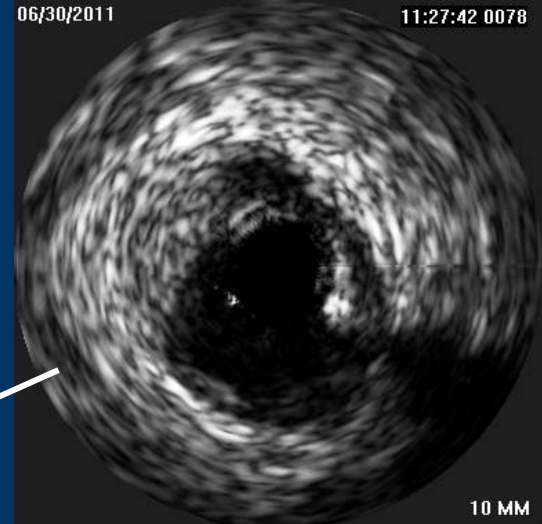
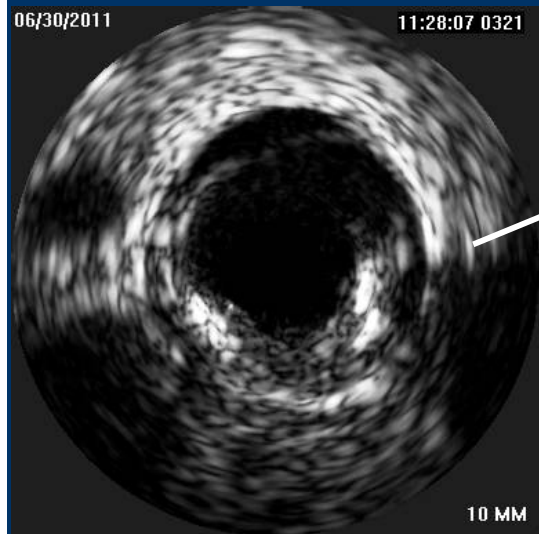
Po 16 hodinách Integrilinu



Po implantaci Stentgraftu + BMS
proximálně

Projasnění RIA pod stentem





Postavení IVUS v katlabu 2011

- **Hodnocení hemodynamické významnosti**
 - v hodnocení hemodynamické významnosti stenózy byla role IVUS významně zpochybněna
- **Hodnocení bifurkačních lézí**
 - nové informace o mechanismu postižení ostia SB
 - vedení intervencí u bifurkací (volba strategie)
 - při hodnocení kmene ACS je vhodnější provádět pullback z obou tepen (rutinně ?)
- **Wall shear stress**
 - parametr hrající zřejmě významnou roli ve vývoje aterosklerózy
- **IVUS vedení intervencí**
 - IVUS vedení implantace DES zřejmě skutečně přináší lepší výsledky
- **Nejasné angiografické nálezy**
 - jednoznačná indikace pro IVUS

Závěr

- V hodnocení hemodynamické významnosti stenózy byla role IVUS významně zpochybněna

Je vhodnější zohlednit v měření významnosti i délku léze ?

TABLE III. Predictors of Physiologic Severity*

	FFR	Pressure gradient
% DS _{QCA}	R ² = 0.10 P = 0.25	R ² = 0.20 P = 0.10
MLD _{QCA}	R ² = 0.25 P = 0.06	R ² = 0.17 P = 0.13
Lesion length _{QCA}	R ² = 0.06 P = 0.40	R ² = 0.07 P = 0.35
MLA	R ² = 0.55 P = 0.003	R ² = 0.52 P = 0.003
AS	R ² = 0.55 P = 0.004	R ² = 0.64 P = 0.004
L	R ² = 0.23 P = 0.08	R ² = 0.45 P = 0.007
MLA/L	R ² = 0.62 P = 0.005	R ² = 0.77 P < 0.001

*% DS_{QCA}: % diameter stenosis by QCA; MLD_{QCA}: minimum lumen diameter measured by QCA; lesion length_{QCA}: lesion length measured by QCA. Others as in Table II.

TABLE IV. Predictors of Physiologic Parameters

	Regression coefficient	Standard coefficient	P
Multivariate correlates of pressure gradient (n = 14) ^a			
% DS _{QCA}	0.140	0.185	0.336
MLA _{IVUS}	-0.402	-0.050	0.822
AS	34.346	0.548	0.025
L	-0.238	-0.150	0.440
MLA/L	-9.789	-0.693	0.014
Multivariate correlates of FFR (n = 14) ^b			
MLD _{QCA}	6.1 × 10 ⁻²	0.198	0.421
MLA _{IVUS}	9.9 × 10 ⁻³	0.086	0.765
AS	-0.398	-0.439	0.077
L	3.9 × 10 ⁻³	0.170	0.456
MLA/L	0.142	0.696	0.016

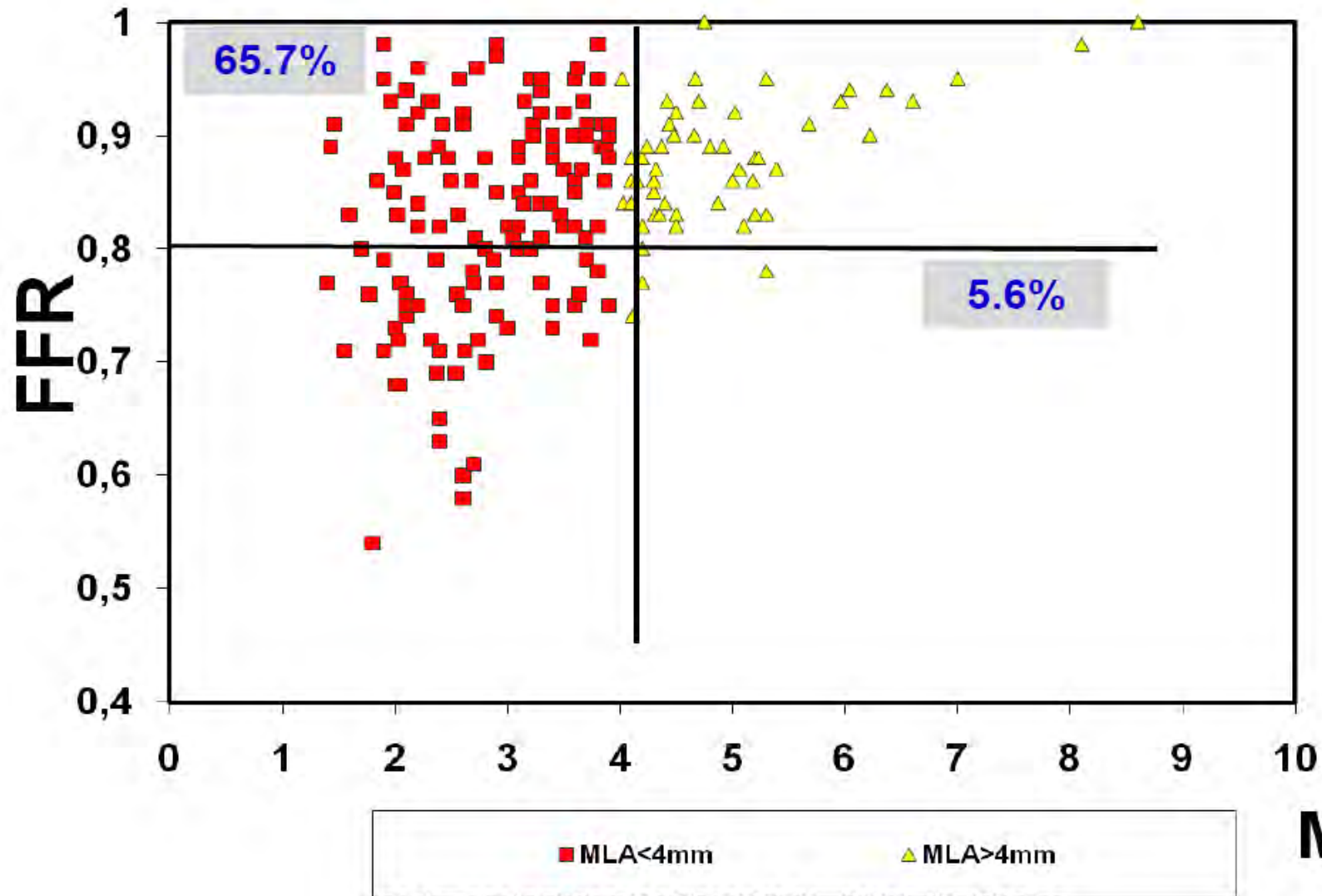
^aMultiple R² value for model = 0.865; F = 10.2; P = 0.003.

^bMultiple R² value for model = 0.847; F = 8.8; P = 0.004.

IVUS vs. FFR

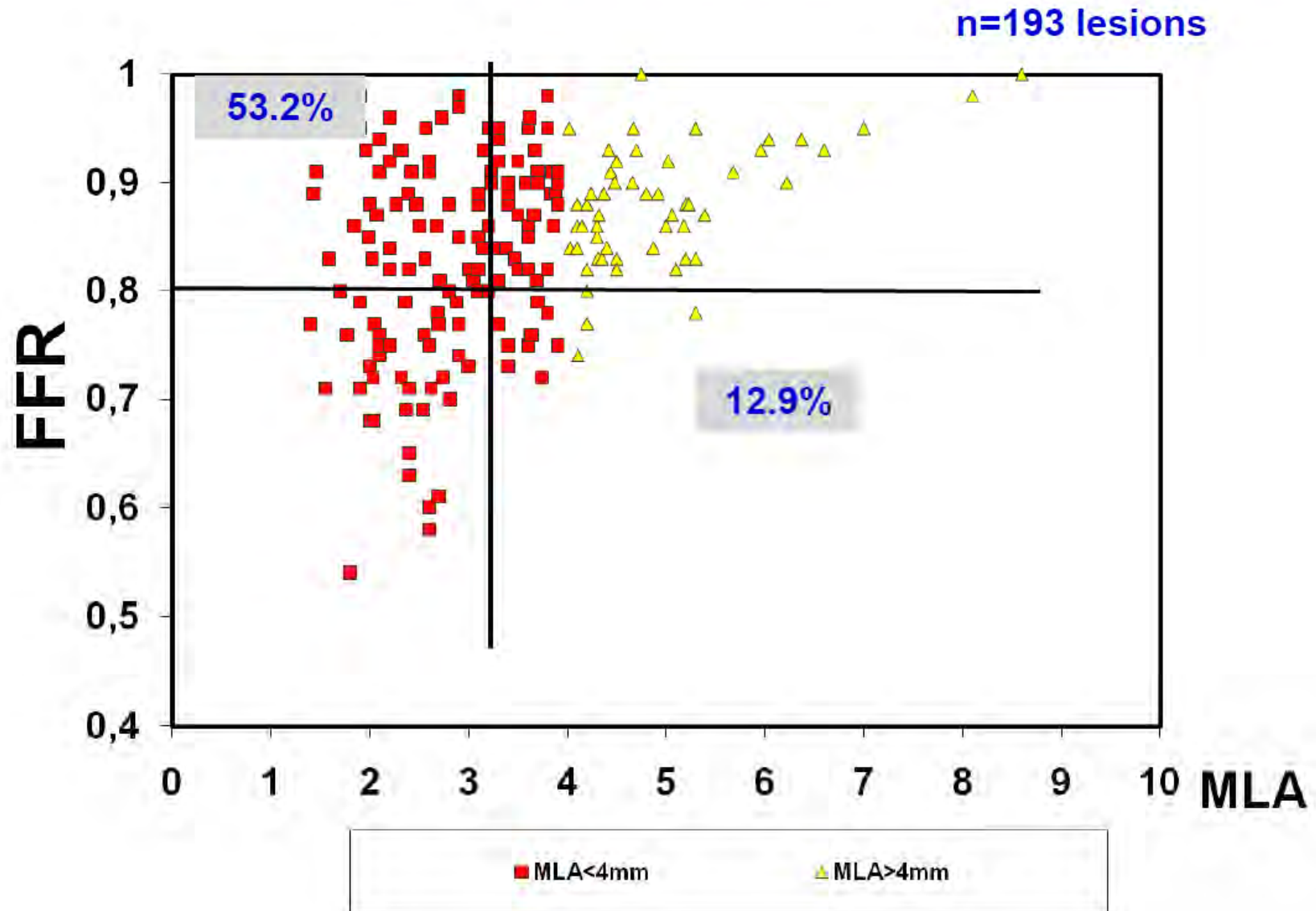
WHC: Ben-Dor et al. Eurointervention In Press

n=193 lesions

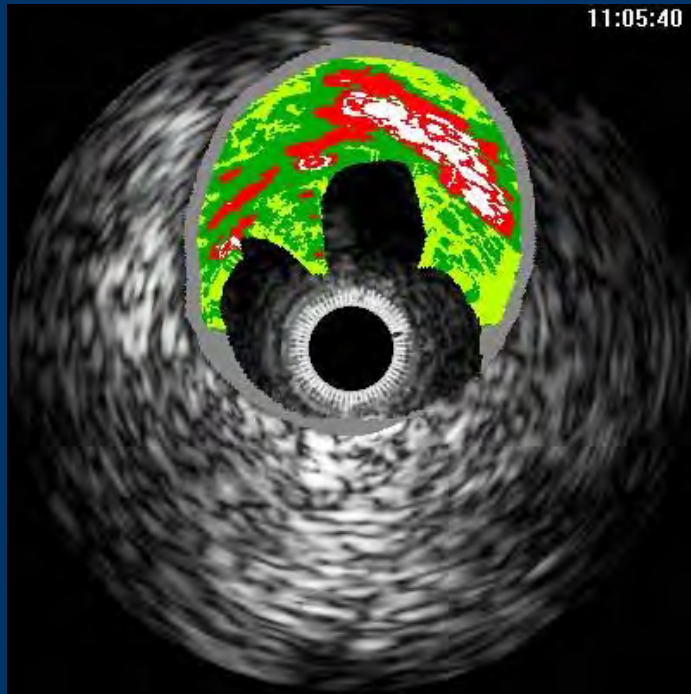


IVUS vs. FFR

WHC: Ben-Dor et al. Eurointervention In Press



Rizikovost léze podle složení plátu



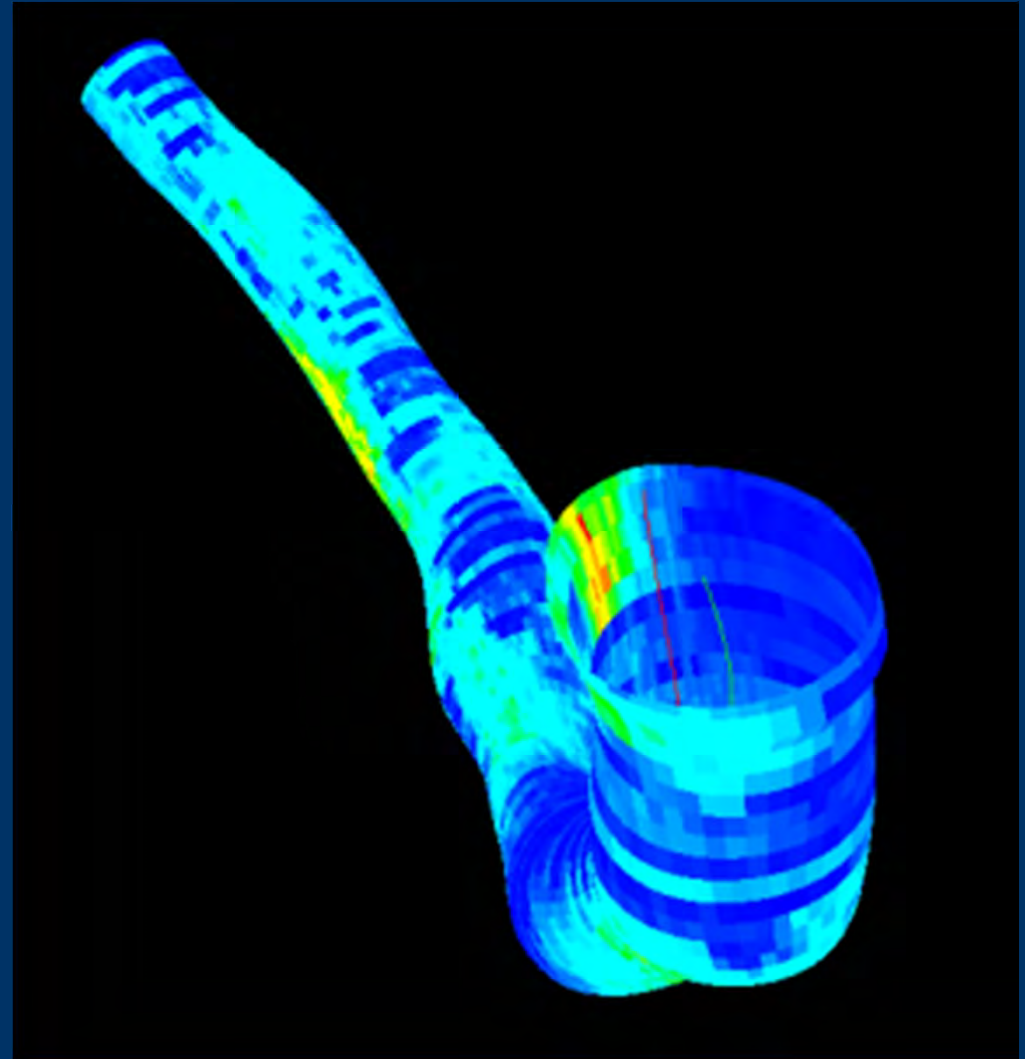
➤ Složení plátu:

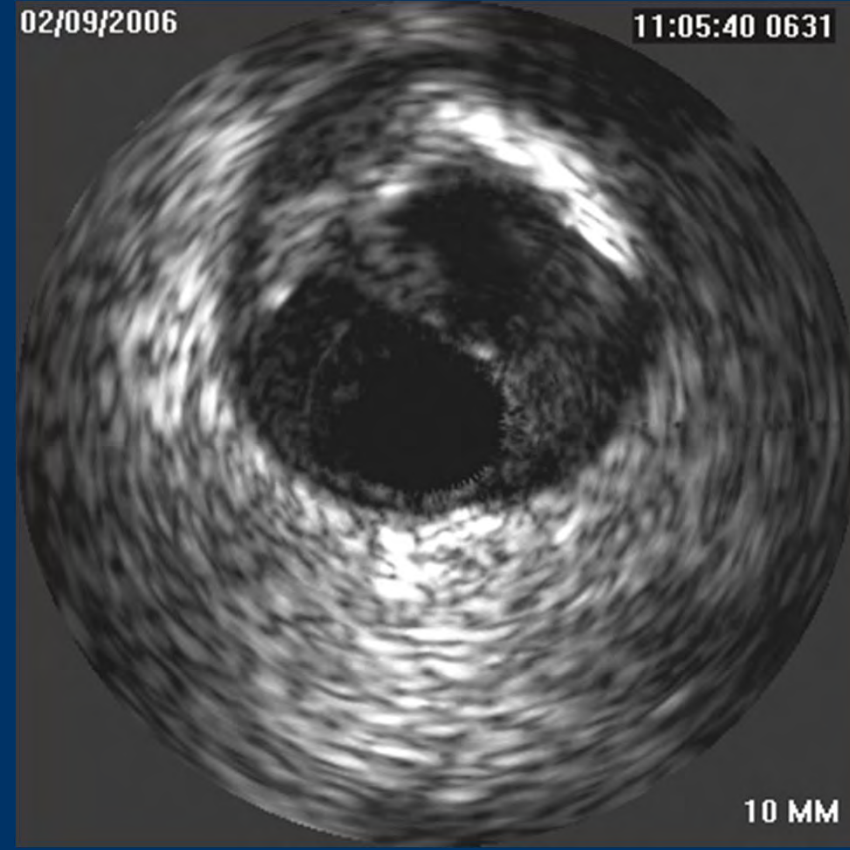
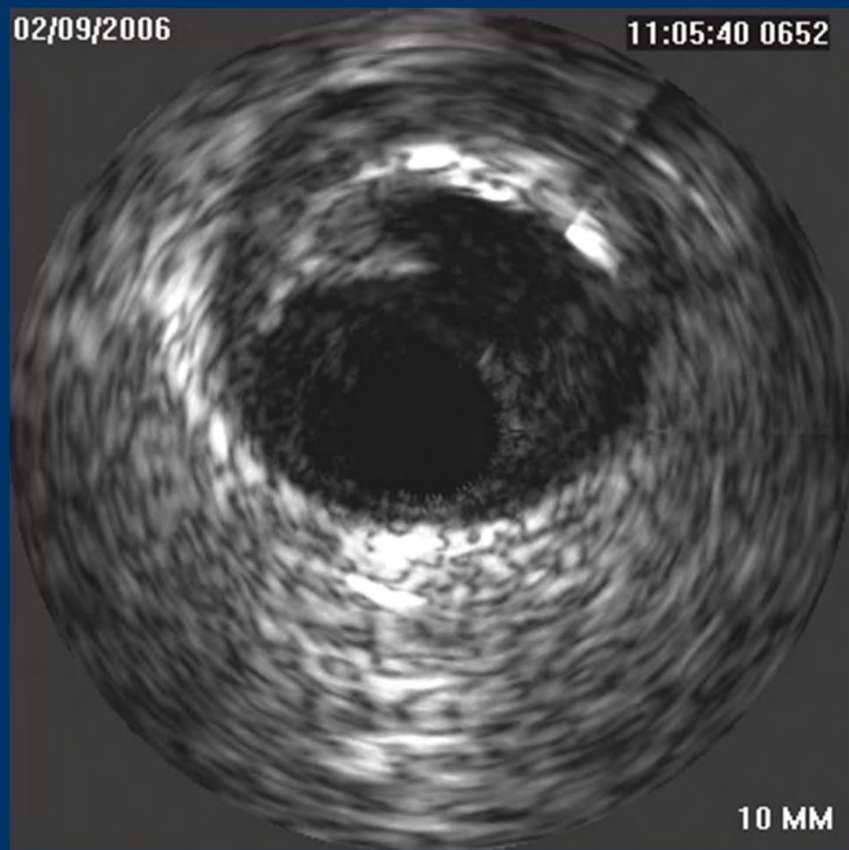
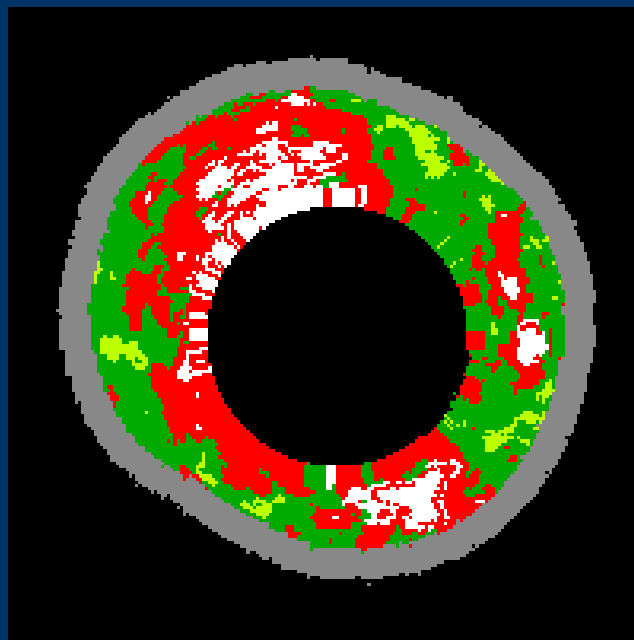
➤ Kalcifikace

➤ Fibrózní tkáň

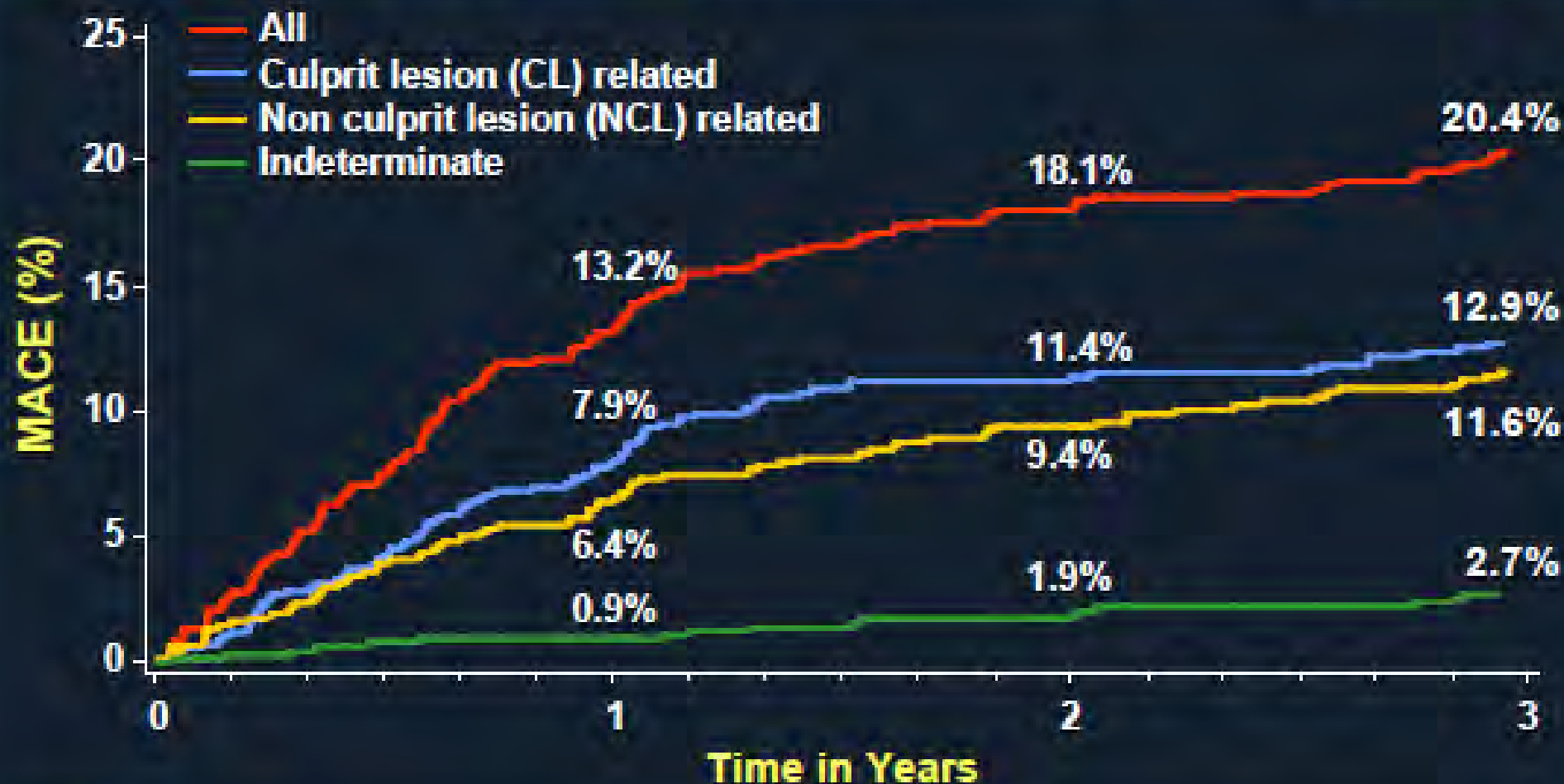
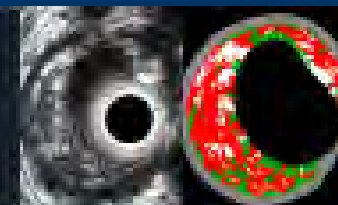
➤ Fibro-lipidová tkáň

➤ Nekrotické jádro





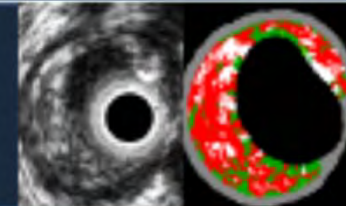
PROSPECT: MACE



Number at risk

	0	1	2	3
ALL	697	557	506	480
CL related	697	590	543	518
NCL related	697	595	553	521
Indeterminate	697	634	604	583

PROSPECT: Multivariable Correlates of Non Culprit Lesion Related Events

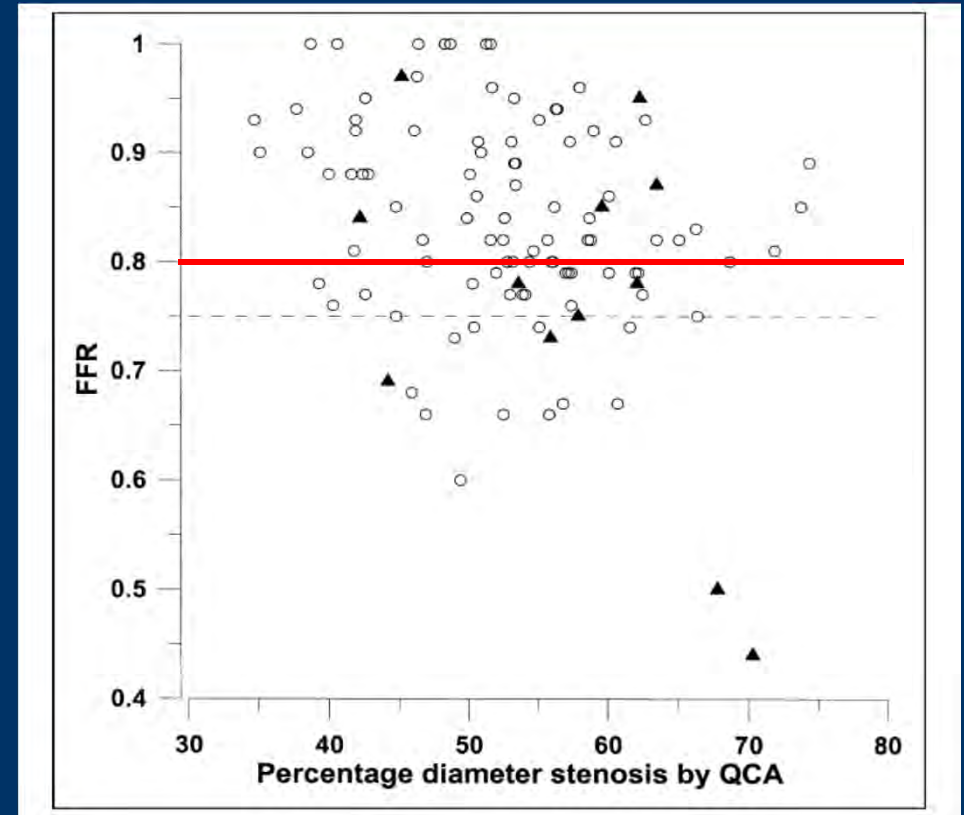
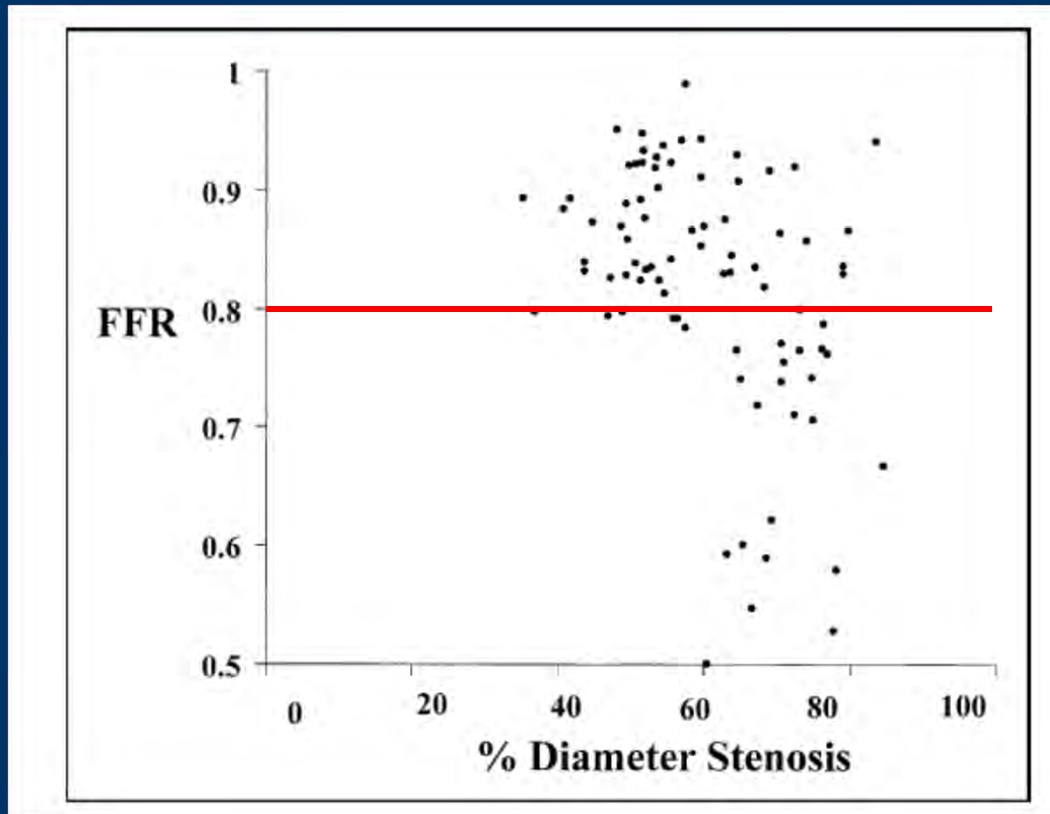


Independent predictors of lesion level events by logistic regression analysis

<u>Variable</u>	<u>OR [95% CI]</u>	<u>P value</u>
$PB_{MLA} \geq 70\%$	4.99 [2.54, 9.79]	<0.0001
VH-TCFA	3.00 [1.68, 5.37]	0.0002
$MLA \leq 4.0 \text{ mm}^2$	2.77 [1.32, 5.81]	0.007
Lesion length $\geq 11.6 \text{ mm}$	1.97 [0.94, 4.16]	0.07
$EEM_{MLA} < 14.3 \text{ mm}^2$	1.30 [0.62, 2.75]	0.49

Variables entered into the model: Minimal luminal area (MLA); plaque burden at the MLA (PB_{MLA}); external elastic membrane at the MLA (EEM_{MLA}) <median; lesion length \geq median (mm); VH-TCFA.

Korelace mezi FFR a angiografickým hodnocením stenózy



Wall / endothelial shear stress

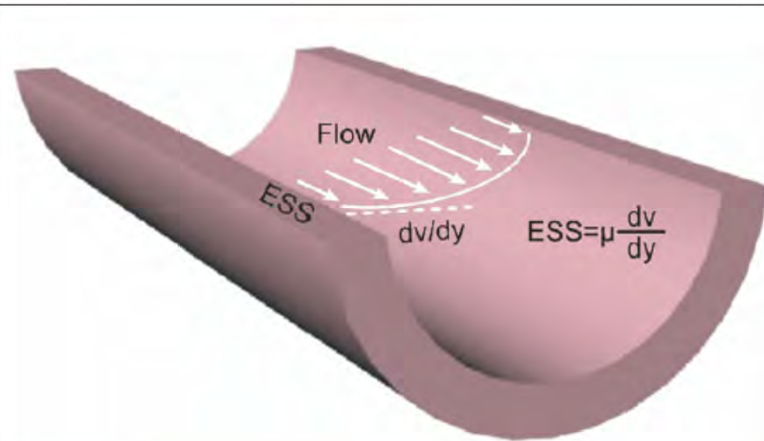
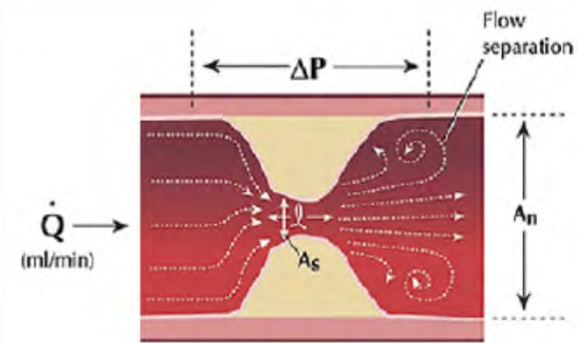
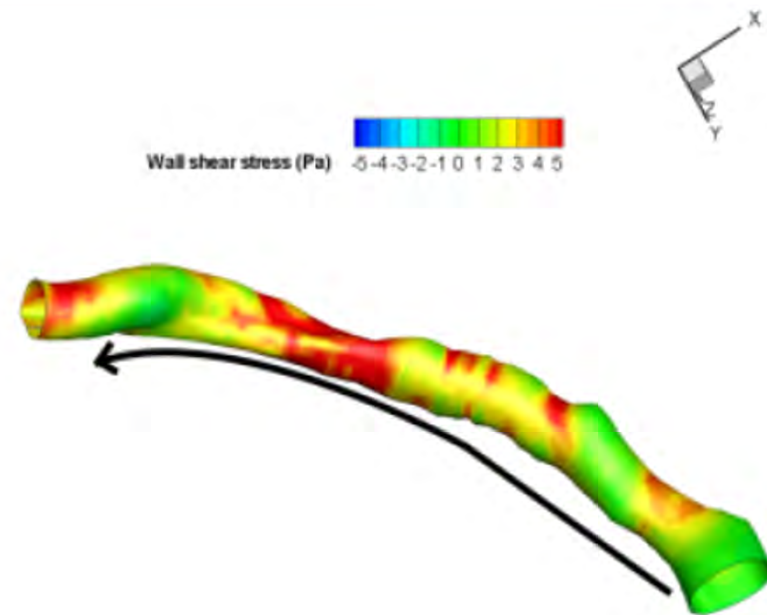


Figure 1 Definition of ESS

Endothelial shear stress (ESS) is proportional to the product of the blood viscosity (μ) and the spatial gradient of blood velocity at the wall (dv/dy).



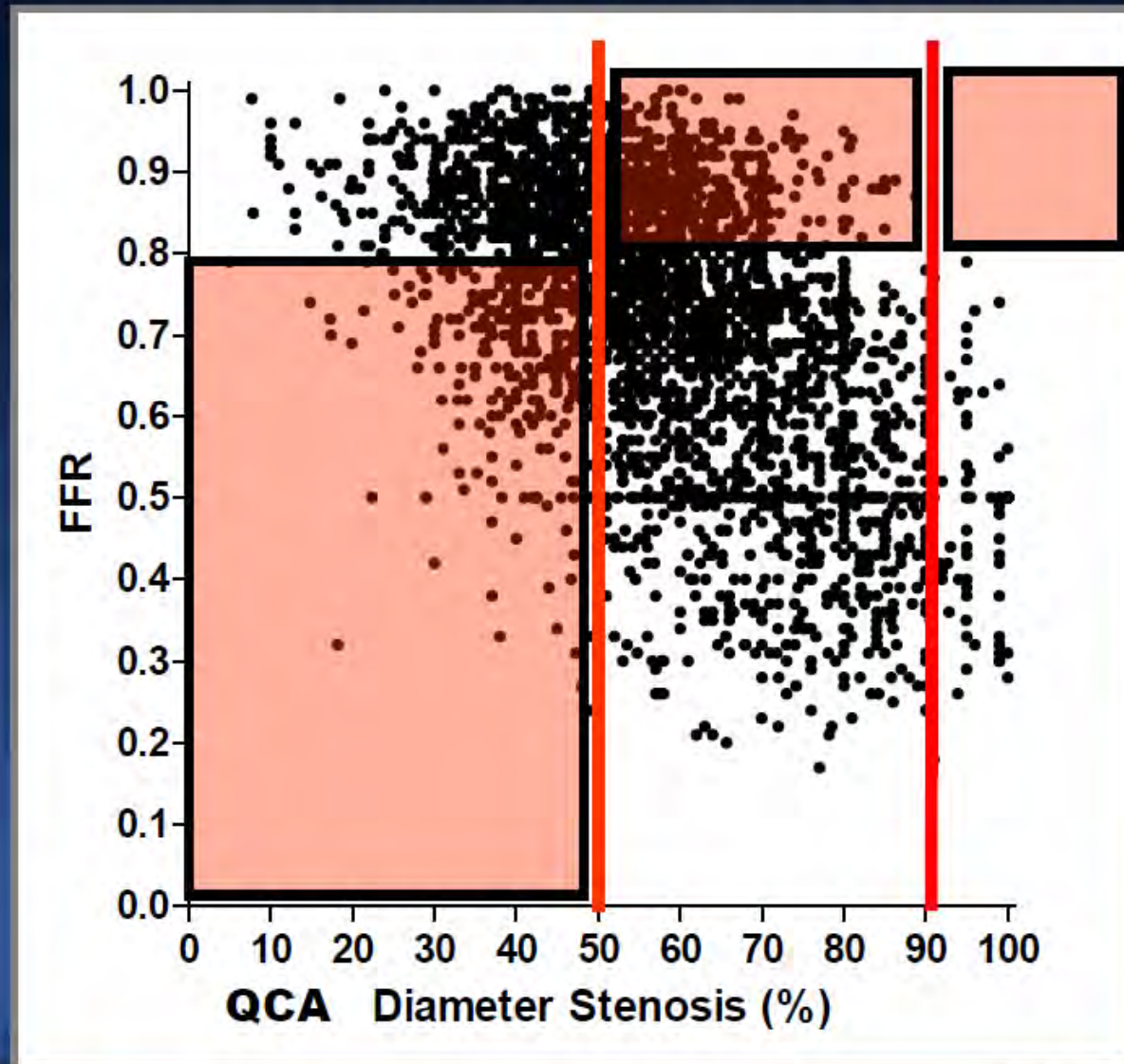
$$\Delta P = \underbrace{f_1(1/A_s^2, l, \dot{Q})}_{\text{Viscous}} + \underbrace{f_2(1/A_s^2, 1/A_n^2, \dot{Q})}_{\text{Separation}}$$

Mismatch Disease in the Cath Lab

Comparison analysis; Angiography vs. FFR (n=3000)

FFR

SLIDE_BACK_수정본



QCA

Courtesy of Bernard De Bruyne, MD, PhD,