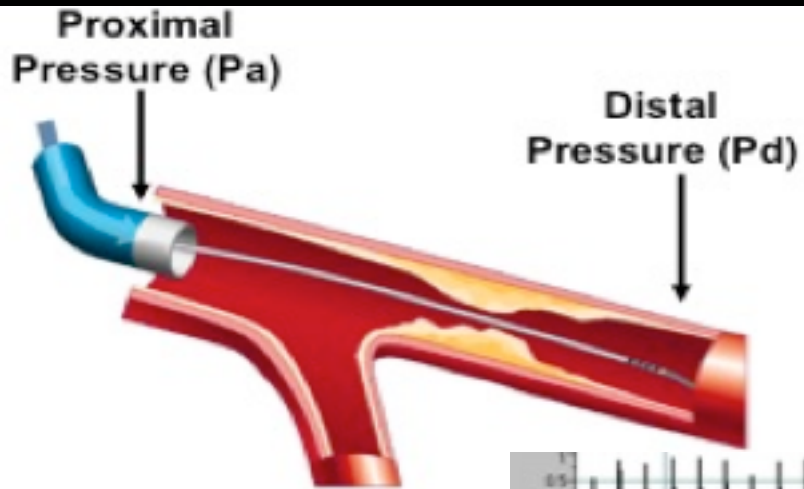


LES TECHNIQUES DE DIAGNOSTIC INTRACORONAIRE: FFR, OCT ET IVUS

*DR ANNE BELLEMAIN-APPAIX
CH D'ANTIBES*

LA MALADIE CORONAIRE: ACTUALITÉS ET INNOVATIONS. SPEED DATA
Amicale des Cardiologues de la Côte d'Azur
Mardi 03 Novembre 2015

FFR: PRINCIPE



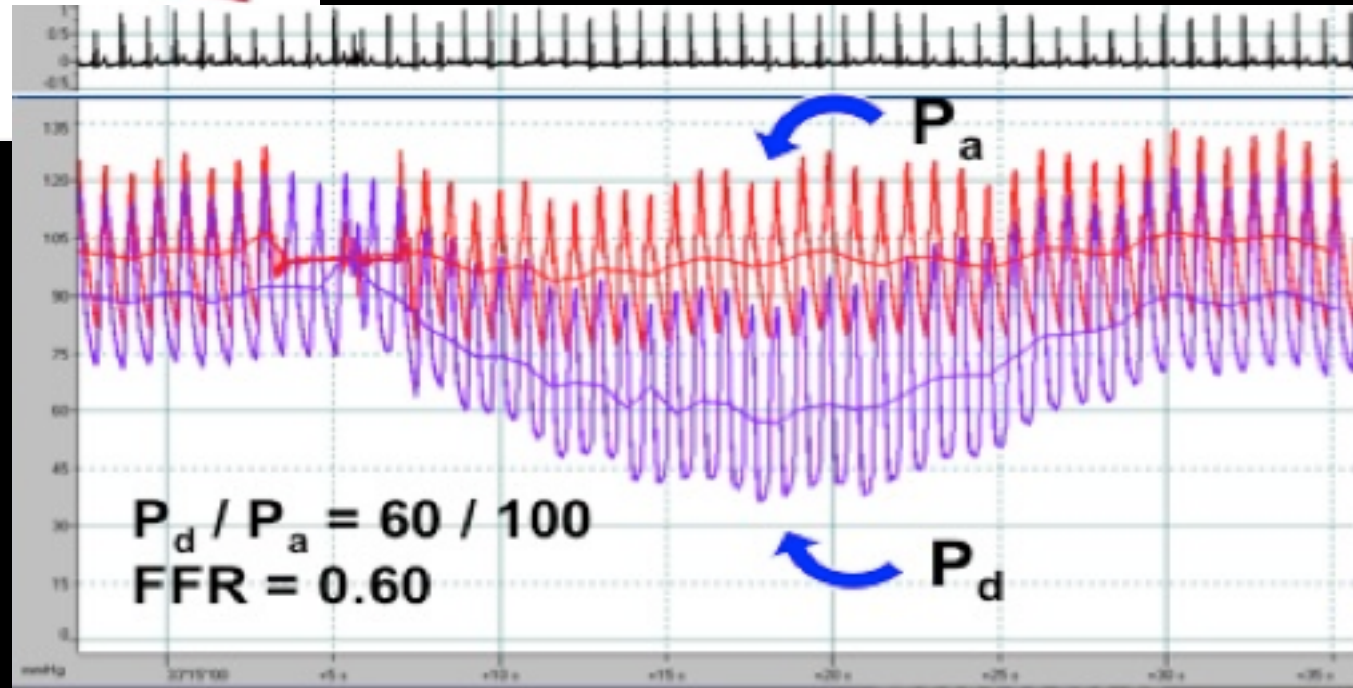
$FFR = P_d / P_a$ lors d'un flux maximal (hyperhémie)

Fiabilité cut-off $< 0,75$: Se 88% Spe 100% VPP

100% VPN 88%

0,75-0,80: zone grise

$> 0,80$: absence d'ischémie



PCI guidée par FFR : Multivessel Disease: FAME 1

Lésions > 50% sur ≥ 2 Vx+ indication supposée de PCI

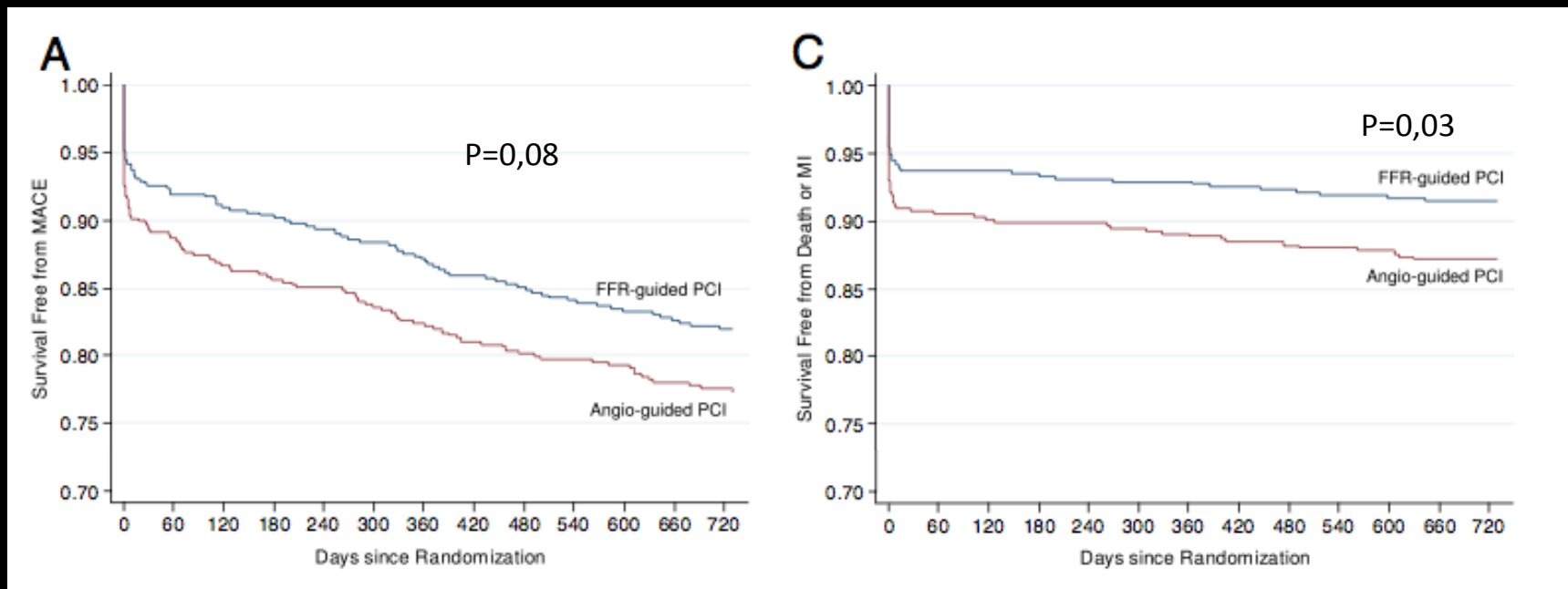
Randomisation PCI guidée ou non par FFR: ATC si $FFR \leq 0,80$

Inclusion des SCA; exclusion TC et CABG

37% des lésions: $FFR > 0,80$

Groupe FFR: Réduction du volume de contraste (272 vs 302), du N stents /p (1,9 vs 2,7)

Temps de procédure idem, COUT final inférieur



Résultats à 2 ans

Evolution stable à 5 ans

Pijls et al; J Am Coll Cardiol. 2010 Jul 13;56(3):177-84

Van Nunen et al; Lancet. 2015 Aug 28

FFR SCAD: FAME 2

De Bruyne et al; N Engl J Med. 2012 Sep 13;367(11):991-1001.

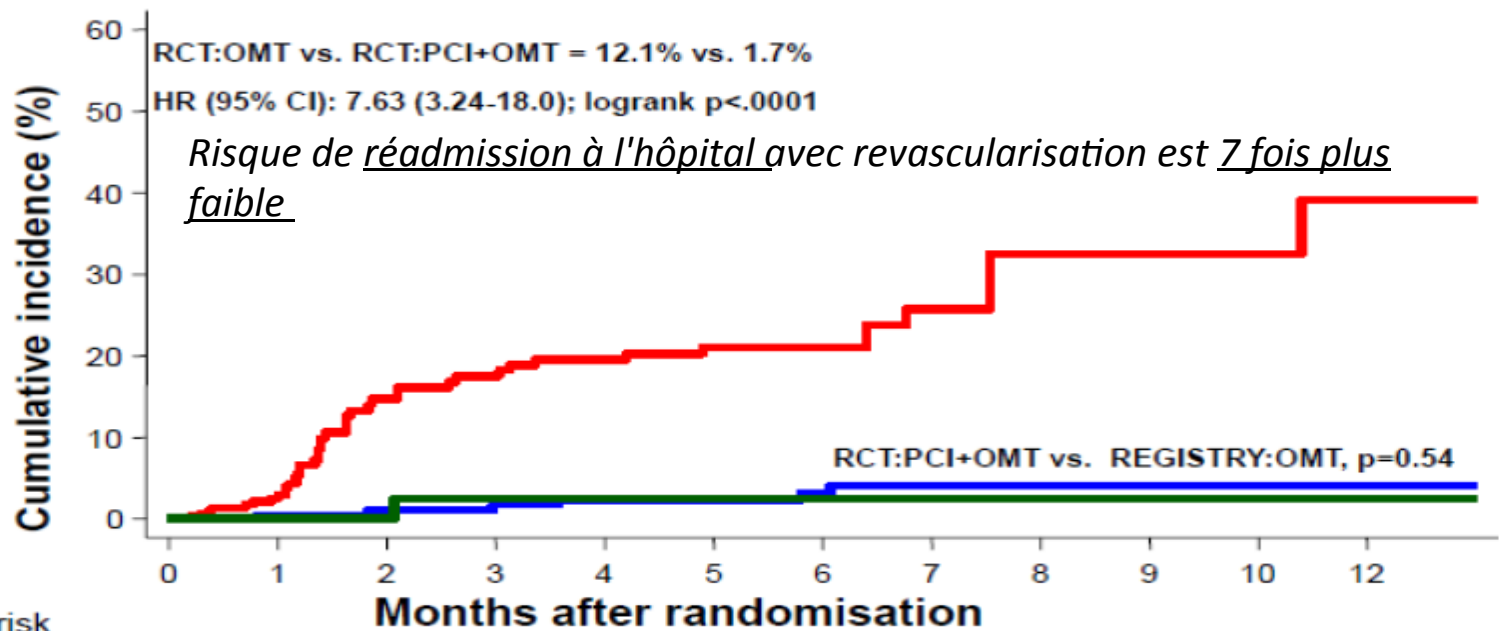
1220 patients, SCAD

888 randomisés (FFR \leq 0,80): OMT vs OMT+PCI

332 registre (FFR $>$ 0,80): OMT seul

PEP: décès IDM UVR

Arrêt prématuré pour supériorité, suivi moyen 213+/-128j



No. at risk	0	1	2	3	4	5	6	7	8	9	10	12
RCT:OMT only	339	238	123	119	115	112	83	20	10	10	10	8
RCT:PCI+OMT	352	256	144	141	140	139	114	25	18	18	18	18
REGISTRY:OMT only	131	88	41	40	40	40	35	4	1	1	1	1

Registre=25% des patients (pas de PCI/FFR): taux MACE 3%

FFR: Guidelines

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	

- Identifie les lésions ischémiantes
- Guide l'angioplastie des multitronculaires

Limites:

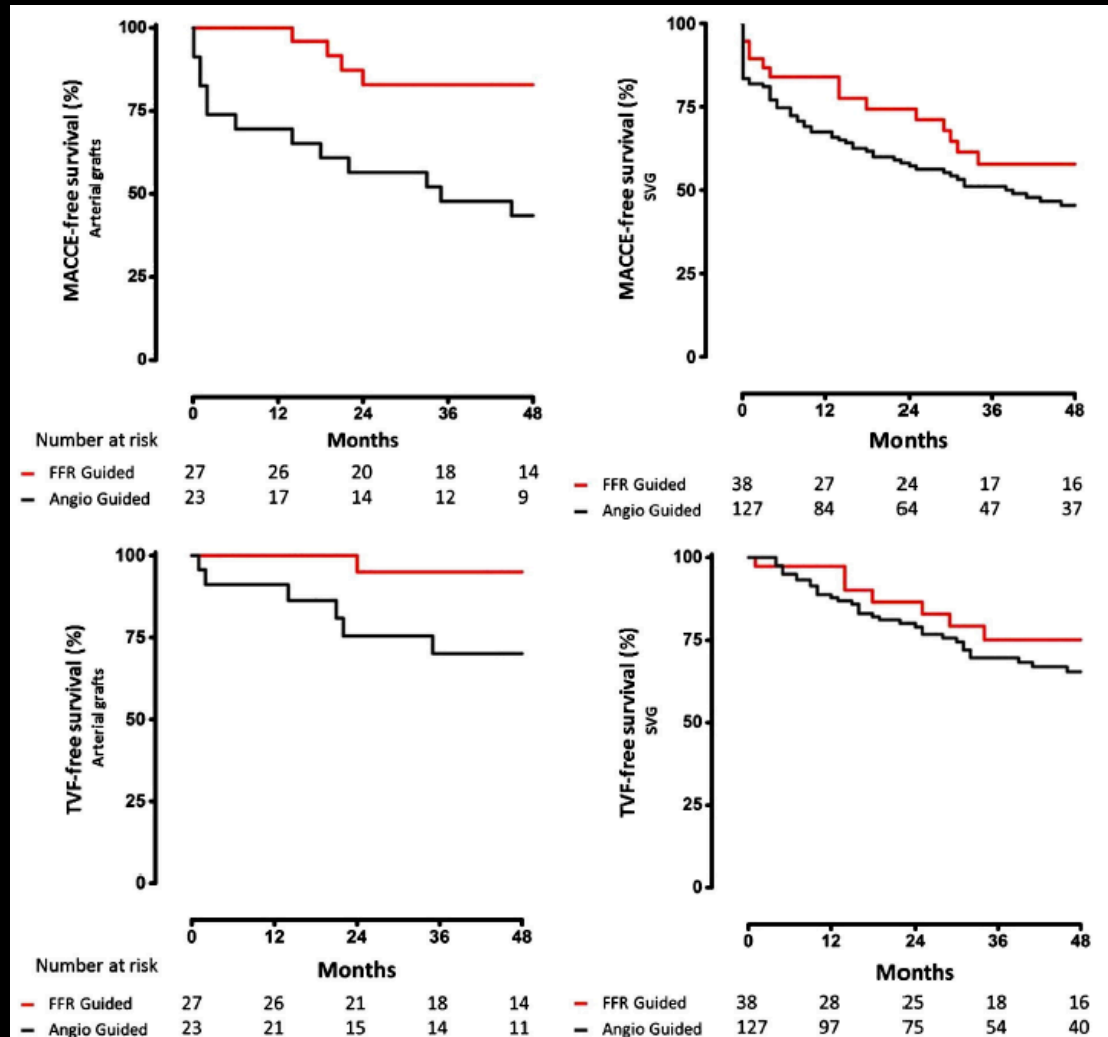
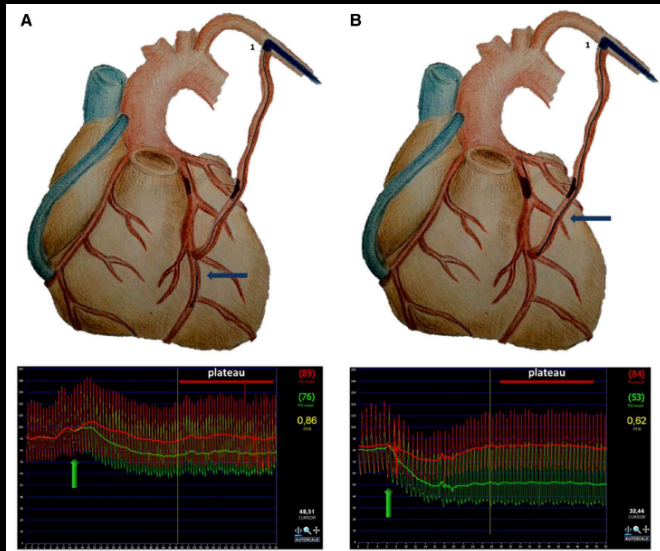
- TC, CABG
- Faux neg: SCA, microvasc, RAP
- FFR post PCI ?

FFR CABG

Registre rétrospectif, sténose 40-70%
 223 patients stable ou SCA tropo –
 FFR 65 pts, PCI 35%
 Angio seule 158 pts PCI 57%
 Suivi 3,8 ans
 MACE 28% vs 51% , HR=0,33, p=0,043
 Réduction coût de procédure

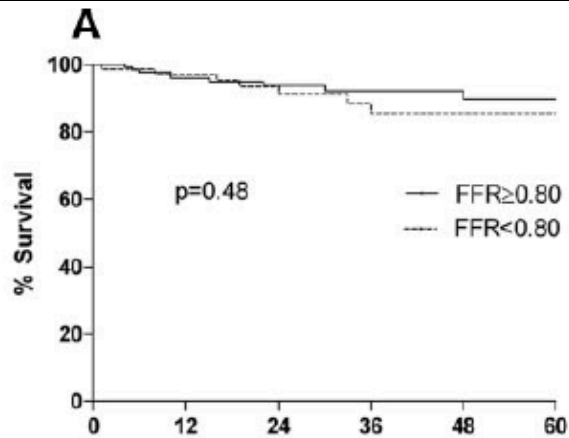
Artériel

Veineux (PMI)



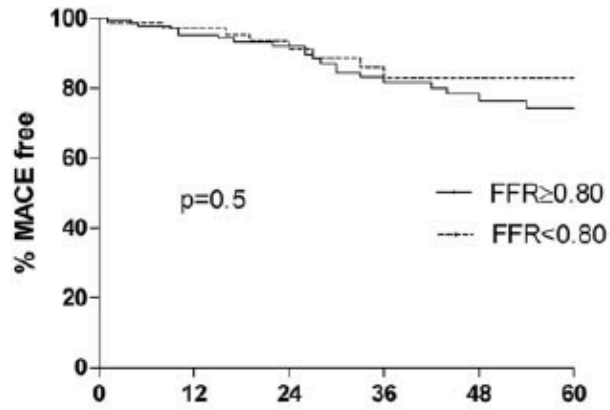
FFR TRONC COMMUN

213 pts, sténose 30-70% TC
 FFR
 $\leq 0,80$: pontage (N=75); sinon TT med
 23% des Tc avec sténose $<50\%$ ont une $FFR \leq 0,80$

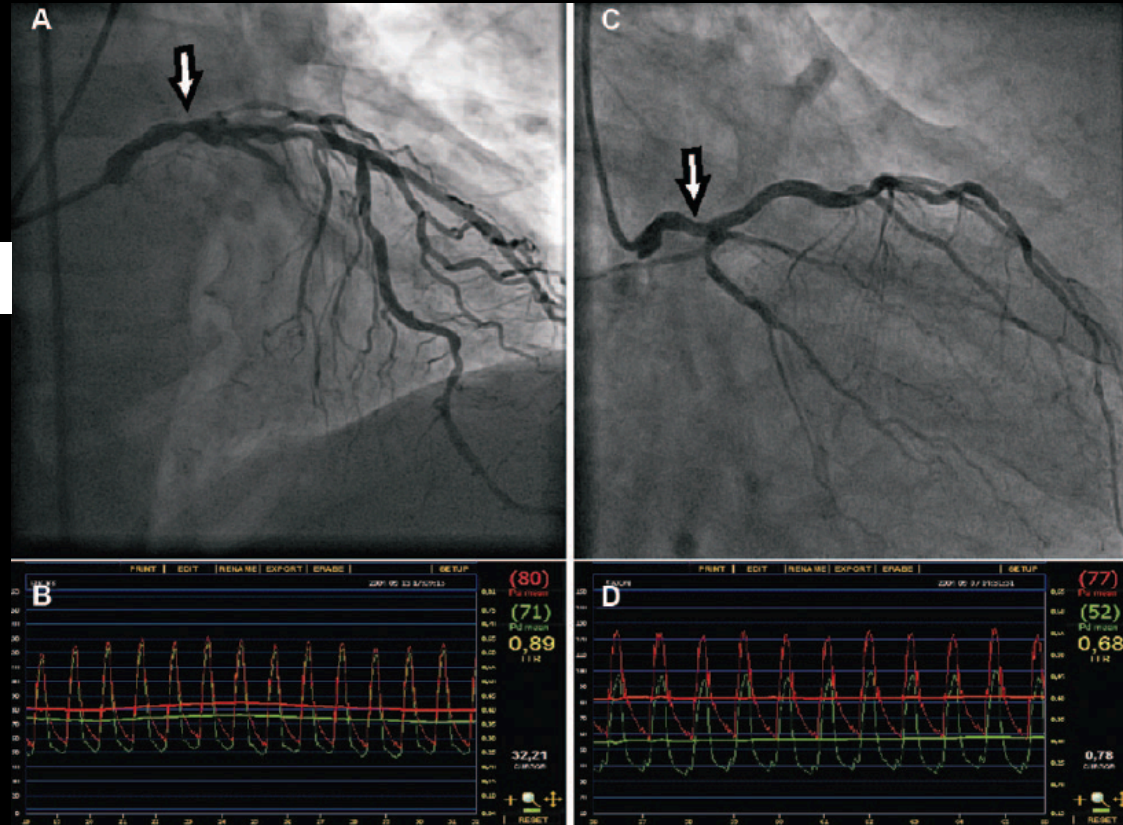


No at risk	Months					
	0	12	24	36	48	60
FFR ≥ 0.80	136	103	72	52	38	26
FFR < 0.80	73	56	41	30	14	10

Survie à 5 ans: idem entre les 2 groupes



No at risk	Months					
	0	12	24	36	48	60
FFR ≥ 0.80	136	106	77	57	42	30
FFR < 0.80	73	56	40	29	15	10

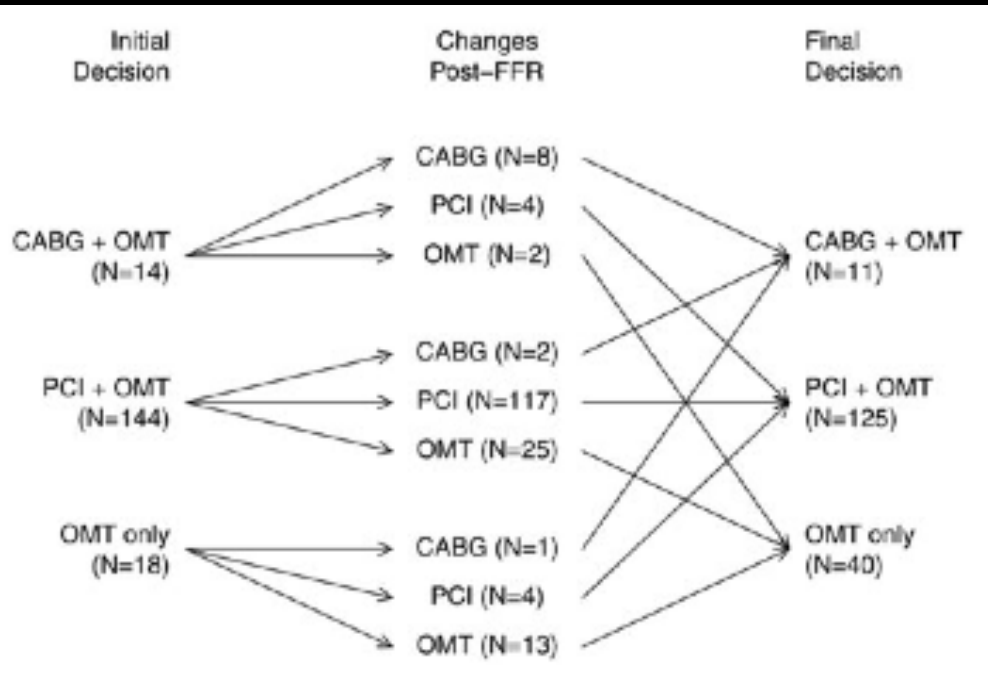


FFR *NSTEMI*: FAMOUS *NSTEMI*

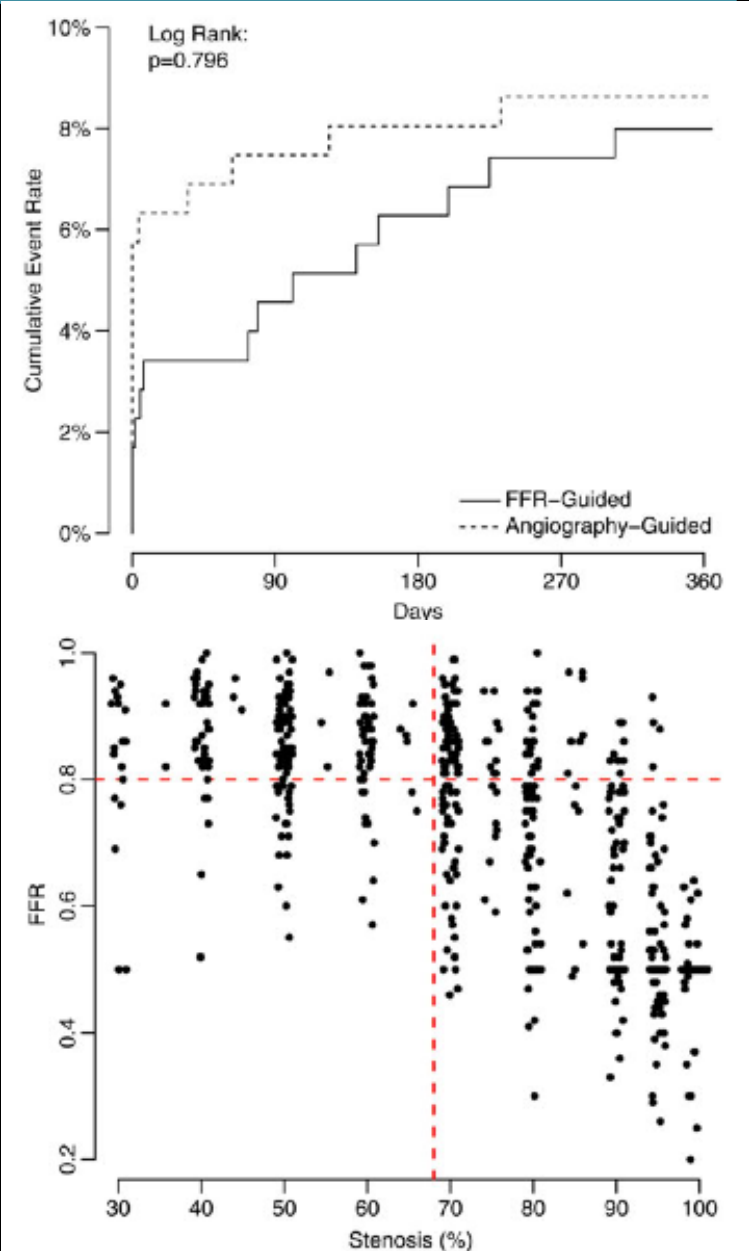
350 NSTEMI

RCT FFR si sténose >30% ou angio seule

PCI si FFR ≤ 0,80



Reclasse 1/5 des décisions



FFR: Remboursement

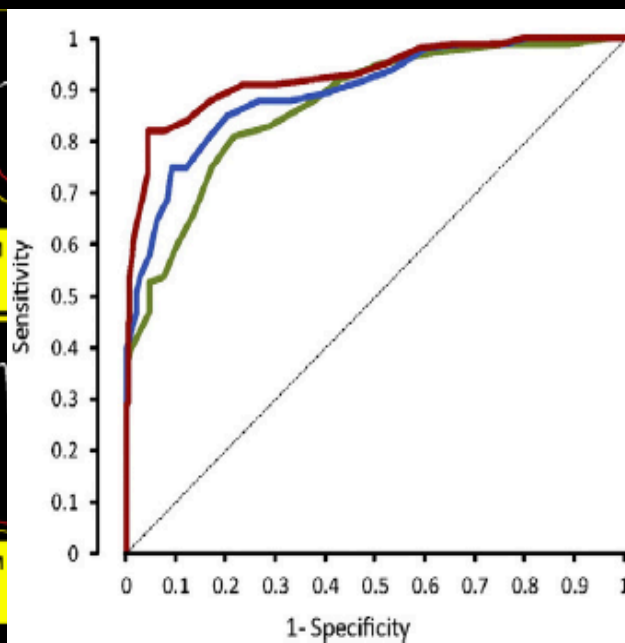
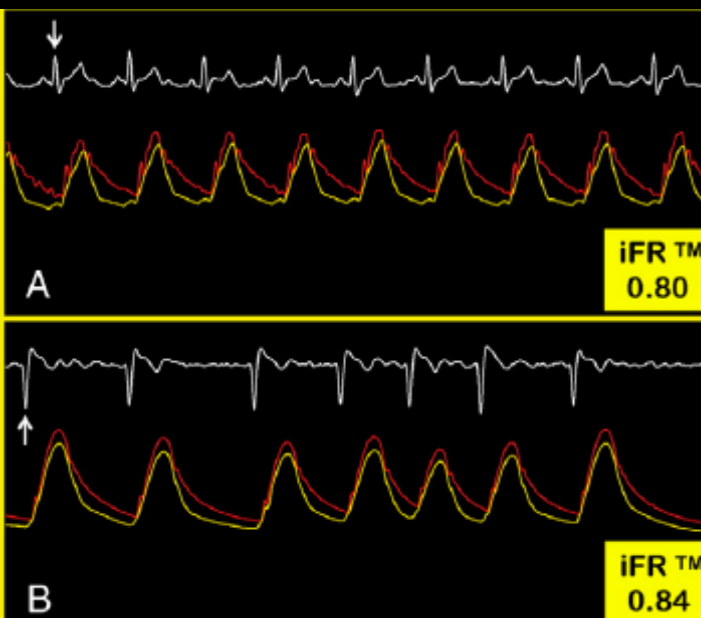
Acte de mesure de la FFR inscrit à la CCAM, à partir du 12 novembre 2015

CODE	LIBELLÉ
DDQF202	Mesure du flux de réserve coronarien [FFR] au cours d'une artériographie coronaire Indications : en situation de coronaropathie stable, en cas de lésions pluritronculaires ou en cas de lésion monotronculaire avec une sténose intermédiaire lorsque les tests d'ischémie myocardiques préalables n'ont pas été contributifs ou été contre-indiqués selon avis de la HAS du 8 avril 2015.

IFR : temps réel sans adénosine VS FFR

IFR: instantaneous wave-free ratio (iFR)

Gradient de pressions trans sténotique, sans adénosine; mesure en diastole, état stable



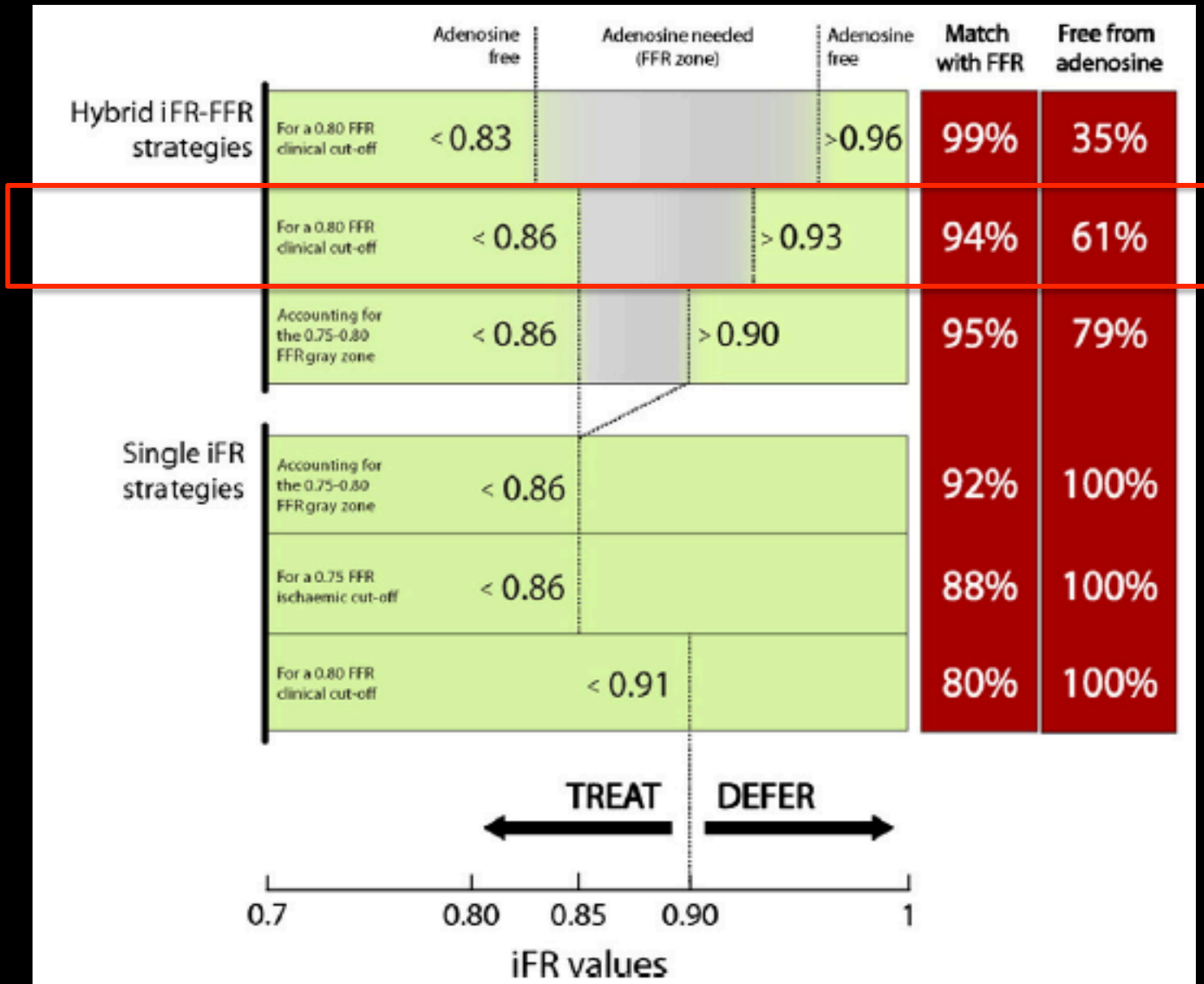
Classification agreement between iFR and FFR

	FFR 0.8	FFR 0.75	FFR gray zone*
iFR cut-off	0.9	0.85	0.85
ROC AUC	0.87	0.90	0.93
Classification match	80%	88%	92%
Sensitivity	81%	75%	82%
Specificity	79%	91%	96%
PPV	71%	70%	86%
NPV	87%	93%	95%

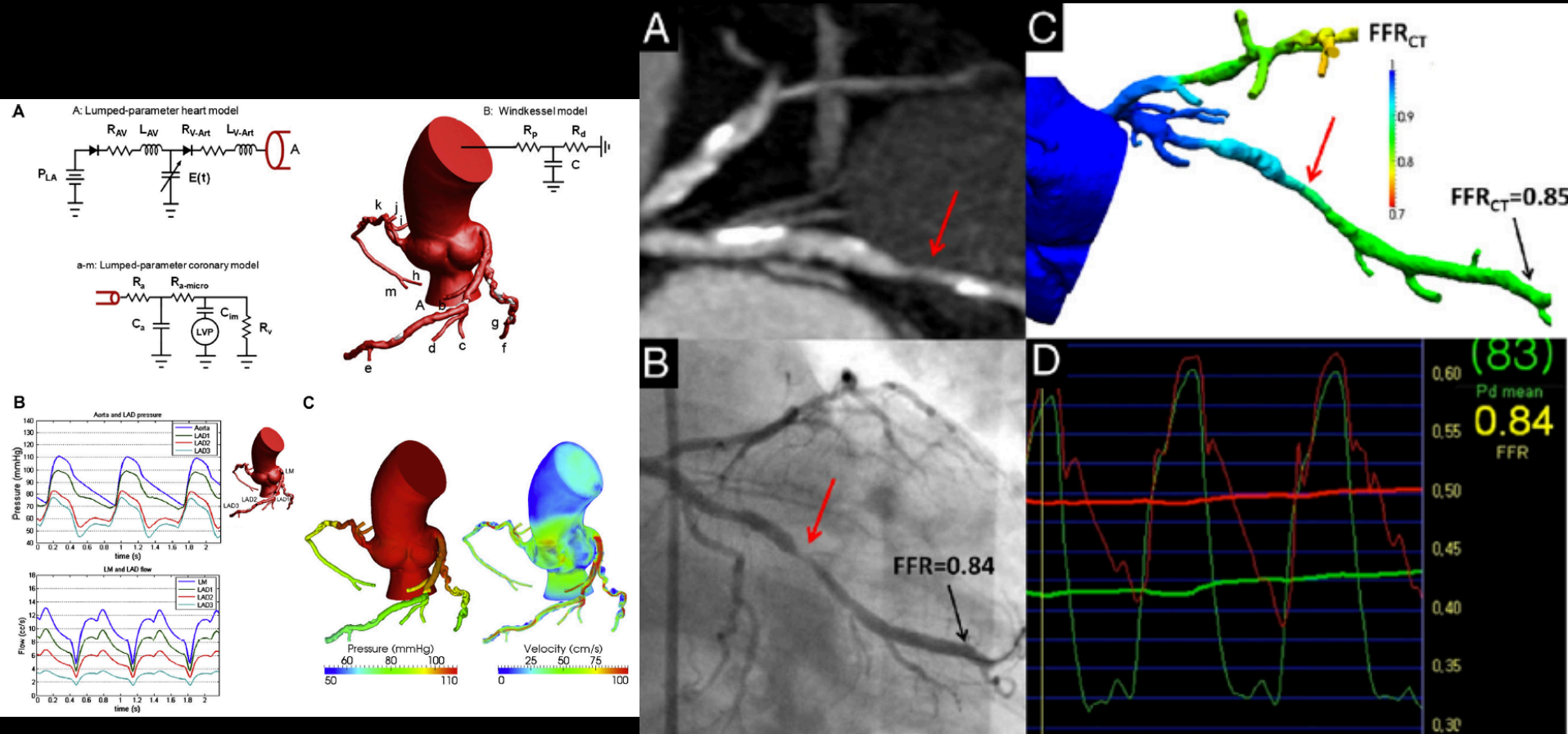
* Accounting for the 0.75 - 0.8 FFR gray zone

Diagnostic agreement between iFR and FFR.

Stratégie hybride iFR-FFR



FFR CTA – modélisation mathématique; dynamique des fluides

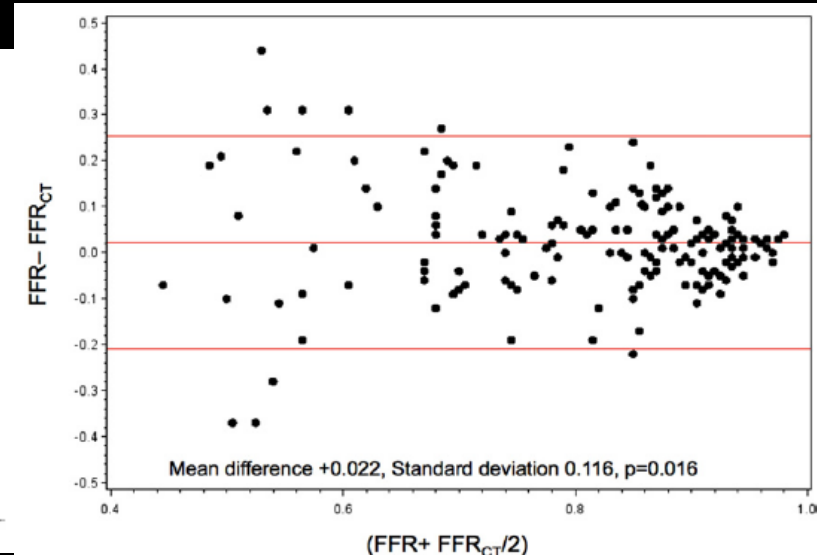
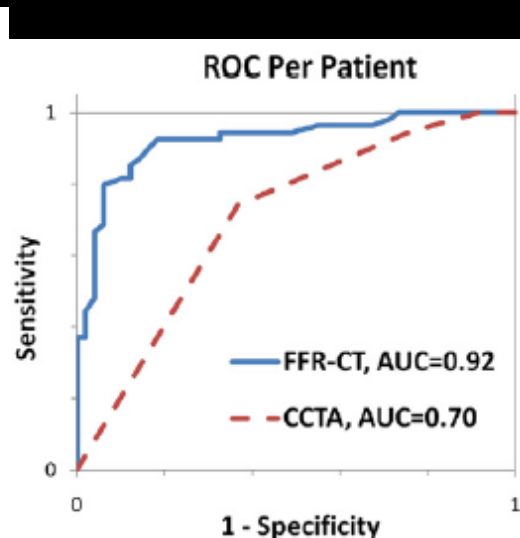
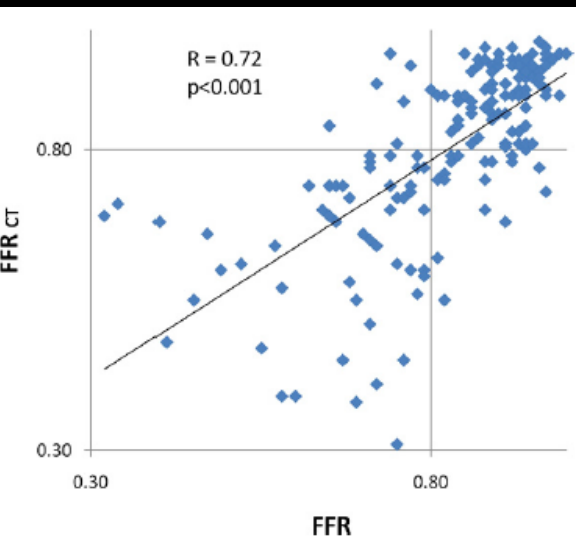


DISCOVER FLOW: fiabilité FFR_{CT}

103 pts, CTA, QCA, FFR

Table 2 Diagnostic Performance of FFR_{CT} and CCTA on a Per-Vessel and -Patient Basis

Measure	Per-Vessel		Per-Patient	
	FFR _{CT} ≤ 0.80 (95% CI)	CCTA Stenosis ≥ 50% (95% CI)	FFR _{CT} ≤ 0.80 (95% CI)	CCTA Stenosis ≥ 50% (95% CI)
Accuracy	84.3 (77.7–90.0)	58.5 (50.4–66.2)	87.4 (79.4–93.1)	61.2 (51.1–70.6)
Sensitivity	87.9 (76.7–95.0)	91.4 (81.0–97.1)	92.6 (82.1–97.9)	94.4 (84.6–98.8)
Specificity	82.2 (73.3–89.1)	39.6 (30.0–49.8)	81.6 (68.0–91.2)	24.5 (13.3–38.9)
PPV	73.9 (61.9–83.7)	46.5 (37.1–56.1)	84.7 (73.0–92.8)	58.0 (47.0–68.4)
NPV	92.2 (84.6–96.8)	88.9 (75.9–96.3)	90.9 (78.3–97.5)	80.0 (51.9–95.7)
LR (+)	4.94 (3.54–6.89)	1.51 (1.33–1.73)	5.03 (3.34–7.59)	1.25 (1.11–1.41)
LR (–)	0.147 (0.097–0.224)	0.22 (0.127–0.370)	0.091 (0.046–0.181)	0.229 (0.097–0.541)



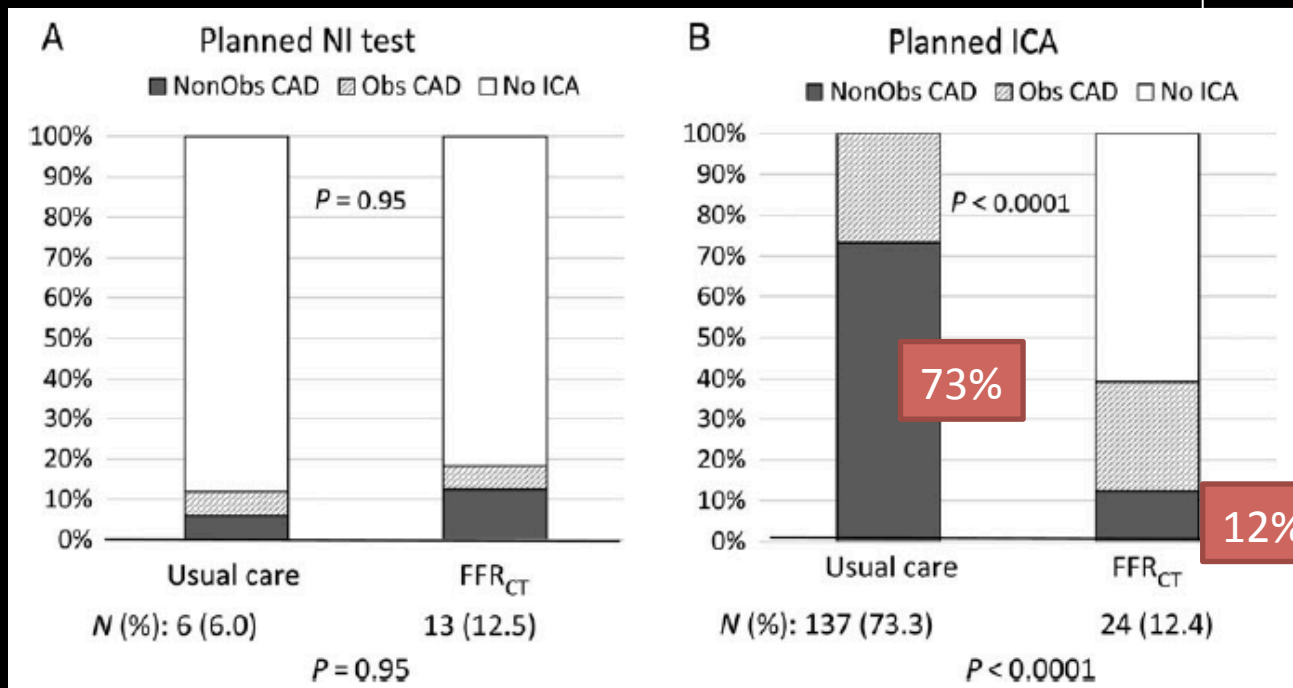
PLATFORM: FFR_{ct} : coût / bénéfice gestion des DT

584 pts avec DT et probabilité prétest d'atteinte coronaire intermédiaire
Cohorte prospective

-Groupe avec coronarographie 1^o intention: FFR_{ct} (N=193) ou CA d'emblée (N=187)

-Groupe test NI

MACEs 9 mois: idem
Radiations: NS (9,9 vs 9,4 mSv)
Coût: -3 391 dollars / usuel



FFR_{ct}: évite 61% de coronarographies avec sténose NS

12% de coro avec SNS (<50%)

IMAGERIE ENDOCORONAIRE

IVUS

OCT

Recommandations ESC 2014

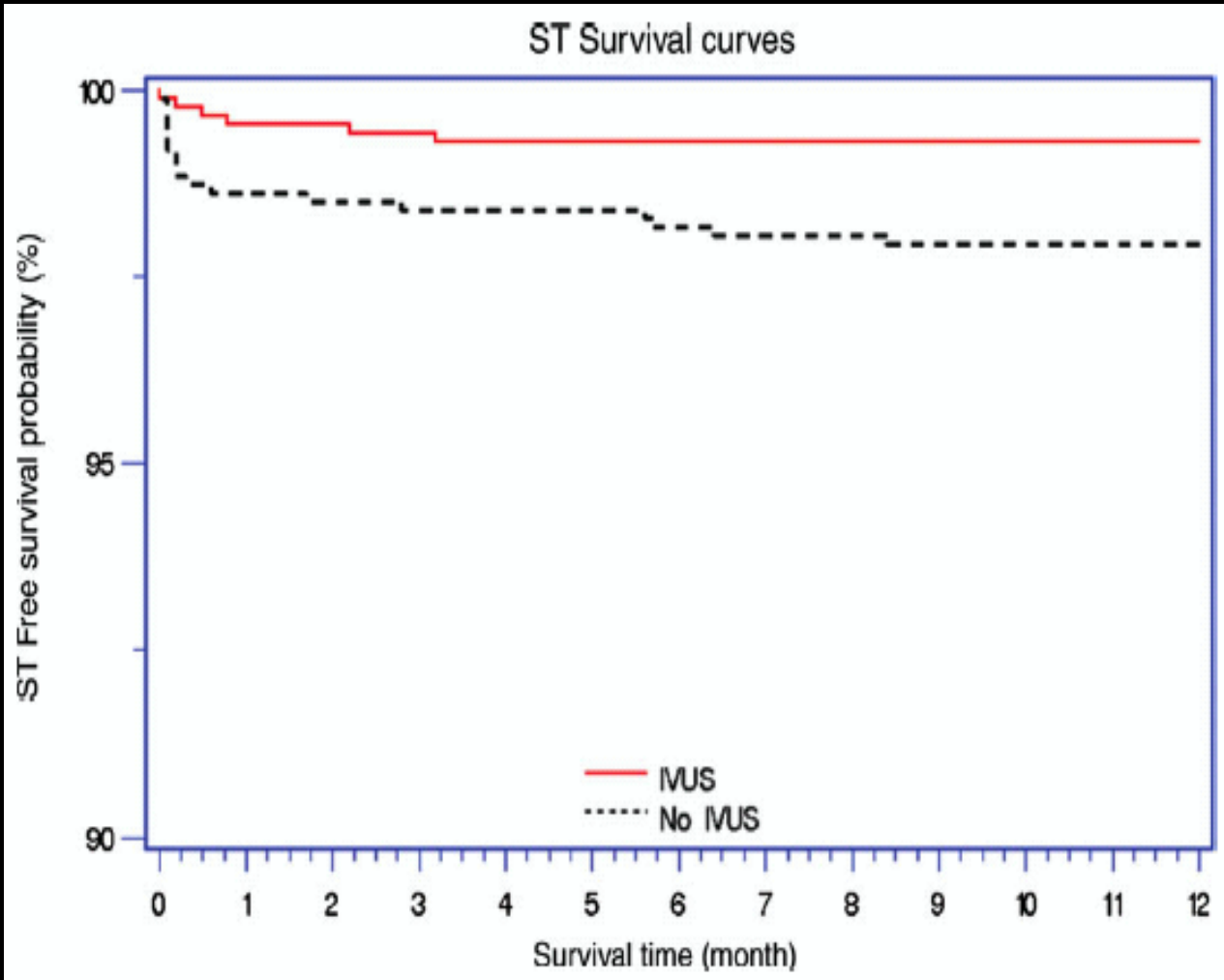
Recommendations for the clinical value of intracoronary diagnostic techniques

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	
IVUS in selected patients to optimize stent implantation.	IIa	B	70
IVUS to assess severity and optimize treatment of unprotected left main lesions.	IIa	B	
IVUS or OCT to assess mechanisms of stent failure	IIa	C	
OCT in selected patients to optimize stent implantation.	IIb	C	

- Optimisation stent
- Sévérité et guidage PCI TC
- Evaluation mécanisme de thrombose ou resténose

	IVUS	OCT
<i>Mécanisme</i>	US	Laser
<i>Résolution</i>	100-150 µm	10 µm
<i>Prof. de pénétration</i>	5 mm	1,5 mm
<i>Intérêt+</i>	Volume de plaque Remodelage Vx Lésions ostiales	Mécanismes Stents
<i>Limites</i>	Struts	Adventice

IVUS: intérêt clinique



884 patients
Random IVUS/no

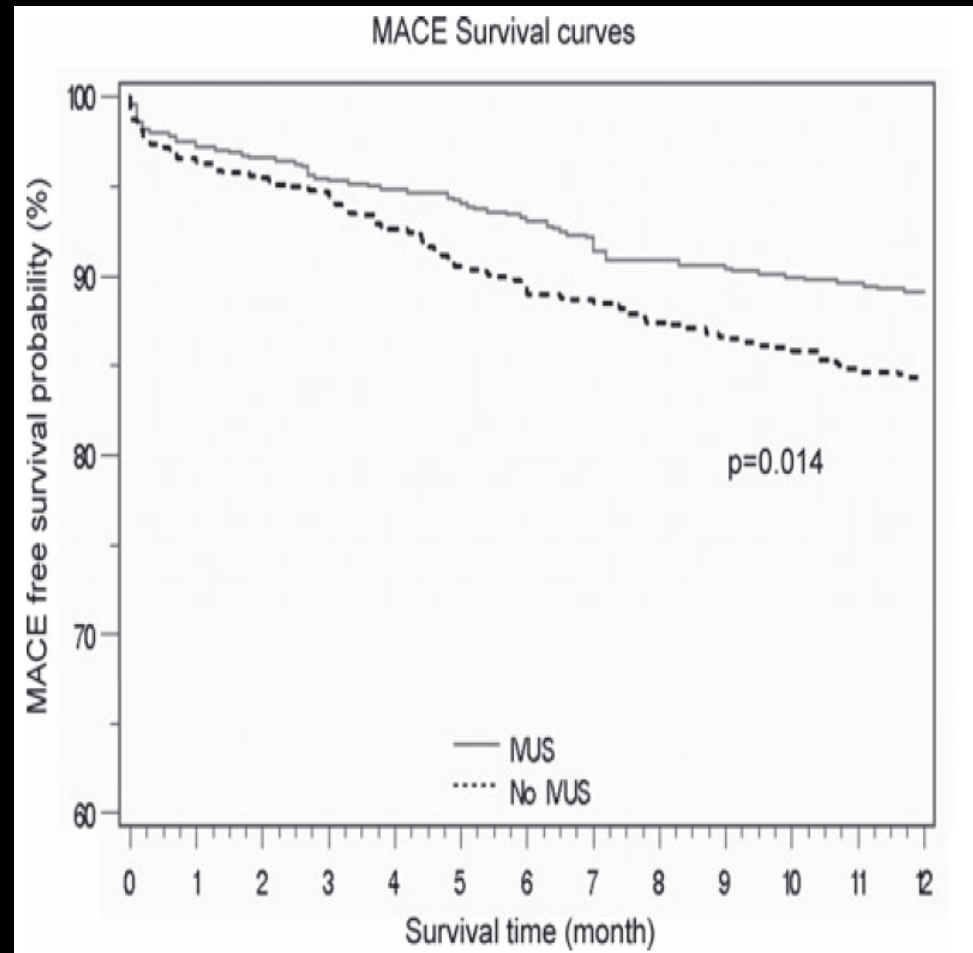
- Meilleure apposition DES
- Réduction des TS J30 A1
- MACEs idem
- Tendance baisse revasc (5,1 vs 7,2% p=0,07)
- Prédicteur indép TS cumul
1an: HR=0,5 (0,1-0,8)p=0,02

IVUS: intérêt clinique: *lésions complexes*

1 984 pts, lésions de type C
IVUS (637) vs angio seule (637)

IVUS:

- -prédilatations
- +post-dilatation
- +cutting balloon
- + succès angio
- ↘MACEs (11% vs 15,6%, $p=0,017$)
- ↘décès CV (1,9% vs 4,4%, $p=0,01$)



IVUS: *TC DES*

MAIN COMPARE study

Registre

SACD SS TC non protégé

IVUS 756 pts vs angio seule 219 pts

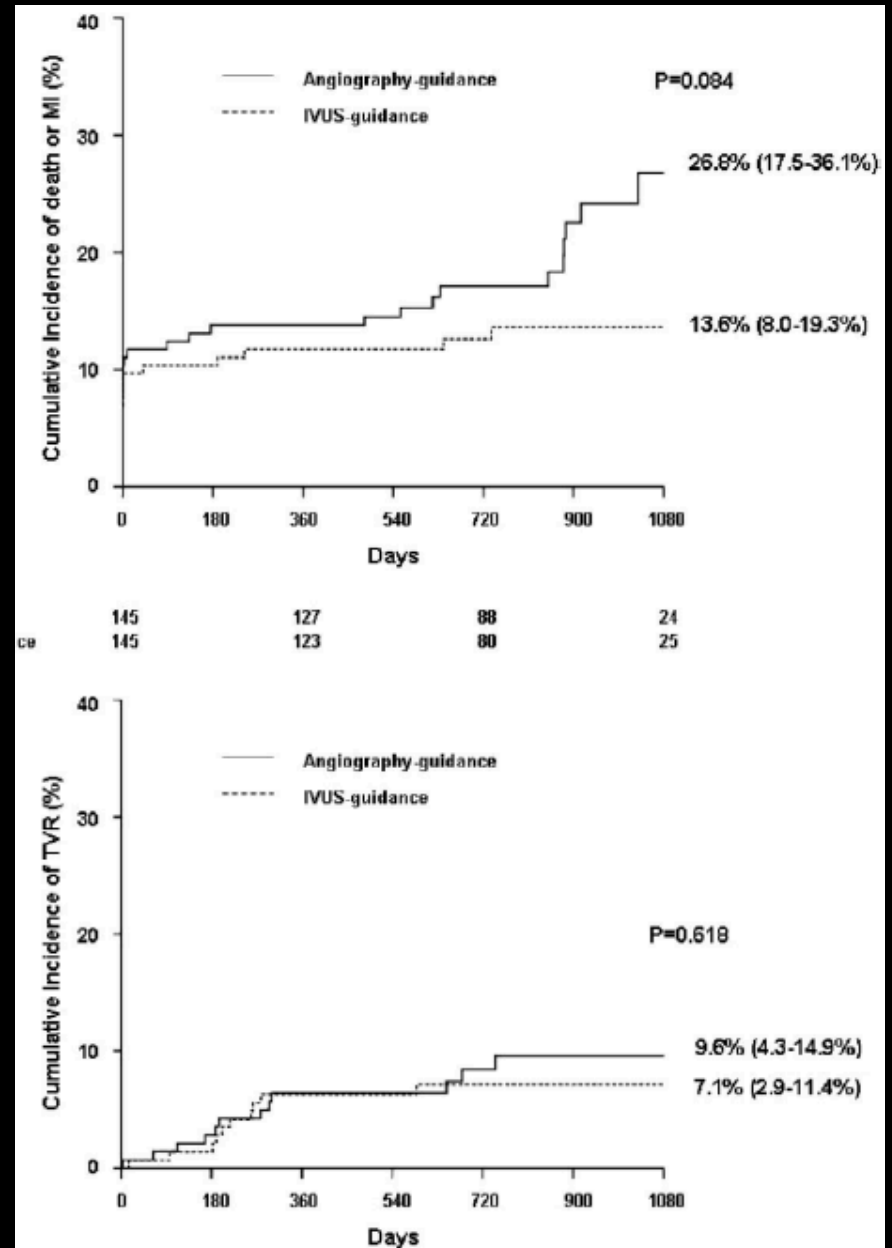
DES 1 génération ou BMS

IVUS et DES:

-réduction décès 3 ans: 4,7% vs 16%, p=0,048

MI, UVR: NS

BMS: NS



IVUS: *Registre PCI 2015*

401 571 PCI, 377 096 angio, 24 475 IVUS

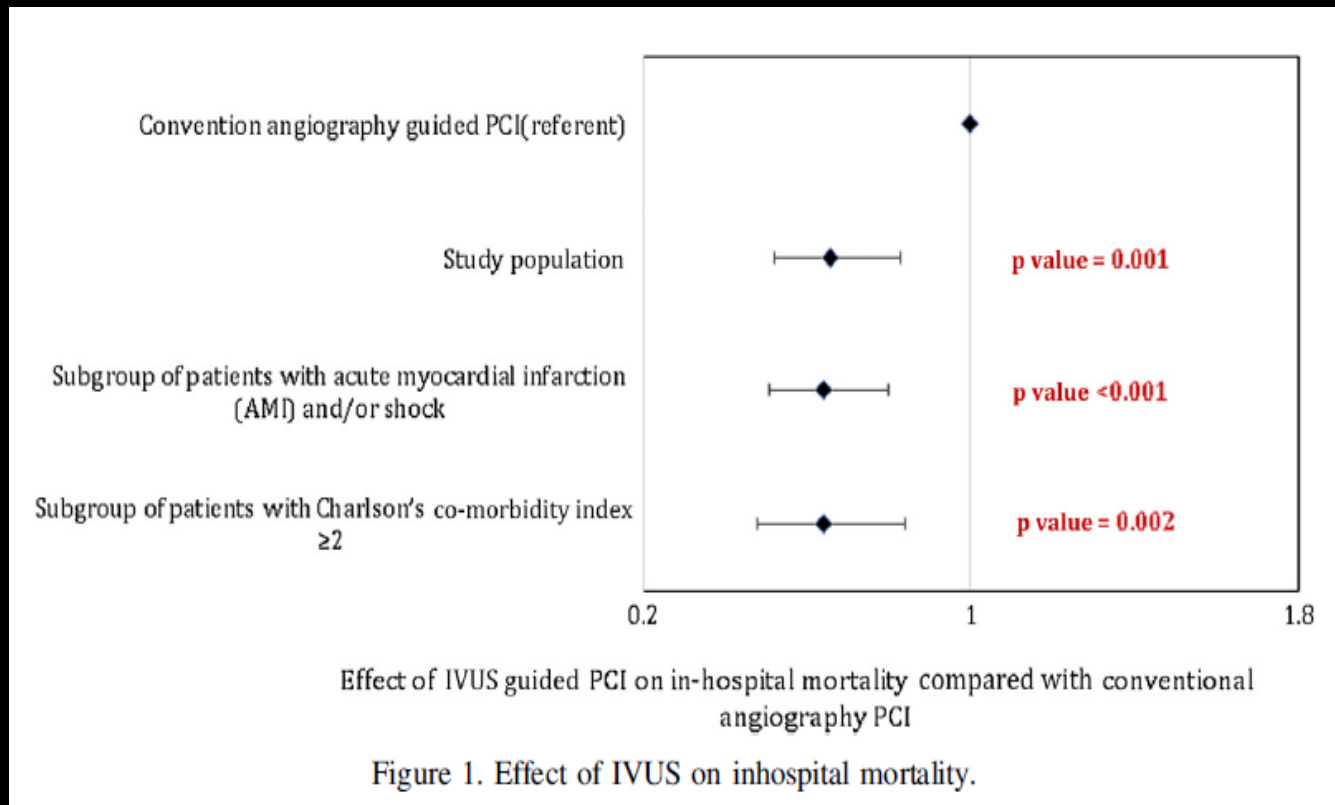
Prédicteurs de mortalité: age, sexe féminin, co-morbidités, STEMI, choc, weekend, urgence
Complications

Prédicteurs de réduction de mortalité: IVUS (odds ratio 0.65, 95%CI(0.52 to 0.83); $p < 0.001$) et volumes PCI

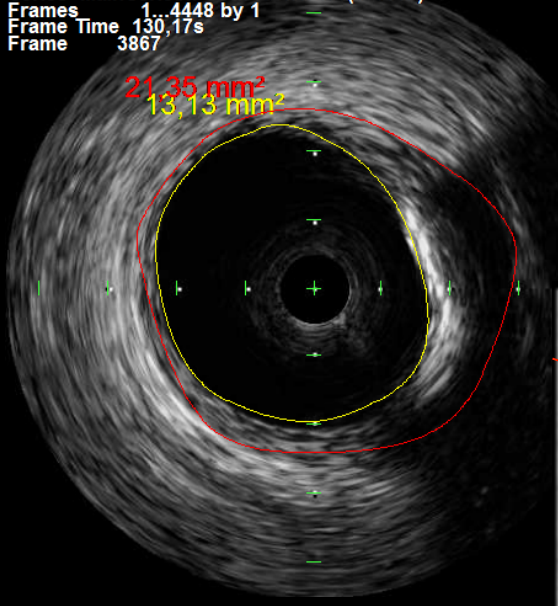
Durée de séjour: idem

Couts et complications augmentées (registre)

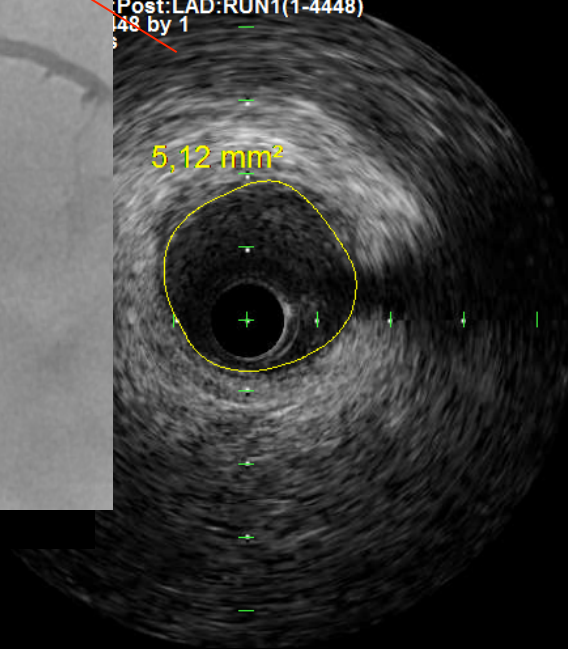
Singh et al; Am J Cardiol. 2015 May 15;115(10):1357-66



Series MainSeries:Post:LAD:RUN1(1-4448)
Frames 1...4448 by 1
Frame Time 130,17s
Frame 3867



Post:LAD:RUN1(1-4448)
48 by 1



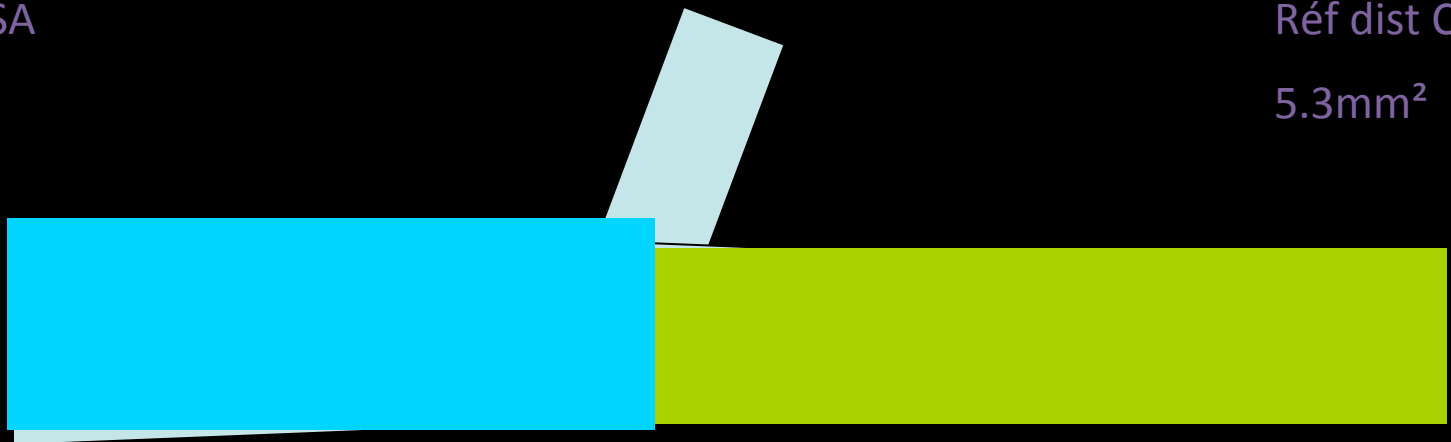
Proposition critères OPERA:

Optimized stenting using : Rationale for simplified criteria:

- Adaptation des critères MUSIC :

Réf prox CSA
13 mm²

Réf dist CSA
5.3mm²



TC

IVA

Réf /segment

4.0 mm (diam ballon)

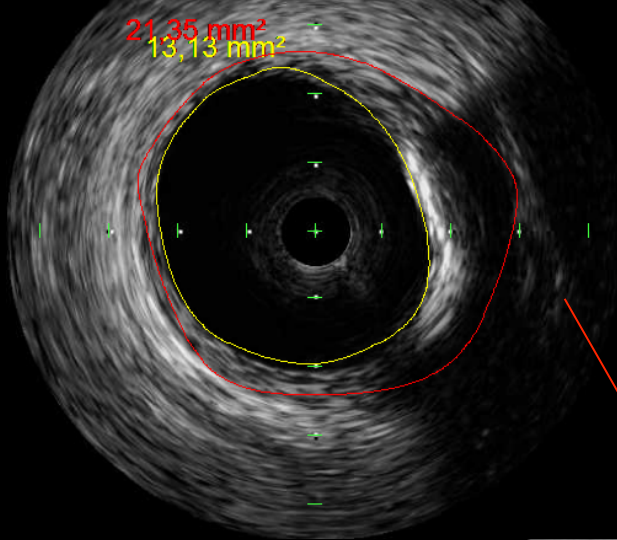
2.5mm (diam ballon)

Objectif

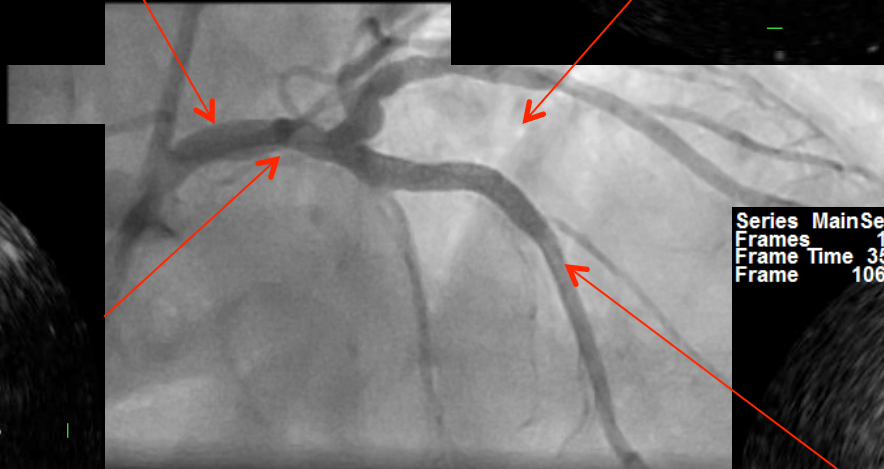
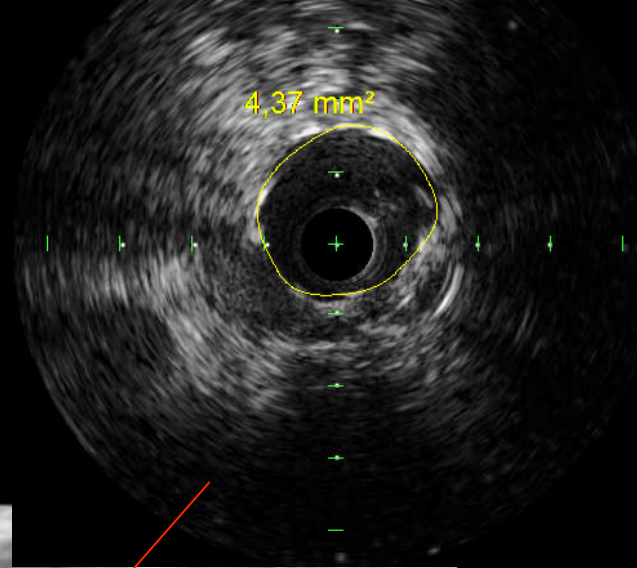
13 x0,8=10.4mm²

5.3 x0,8=4.2mm²

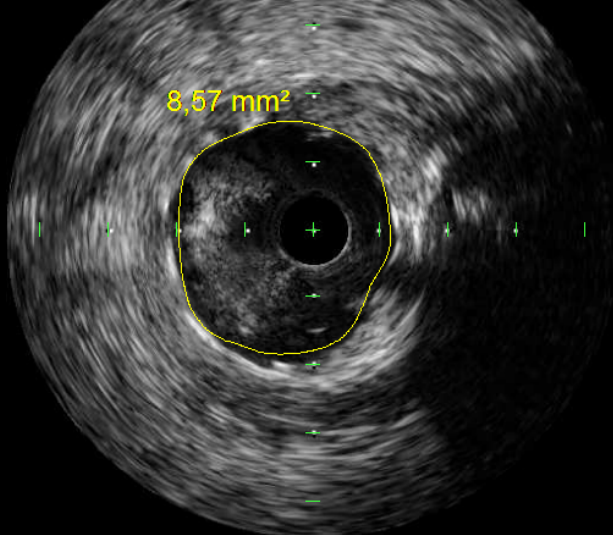
Series MainSeries:Post:LAD:RUN1(1-4448)
Frames 1..4448 by 1
Frame Time 130.17s
Frame 3867



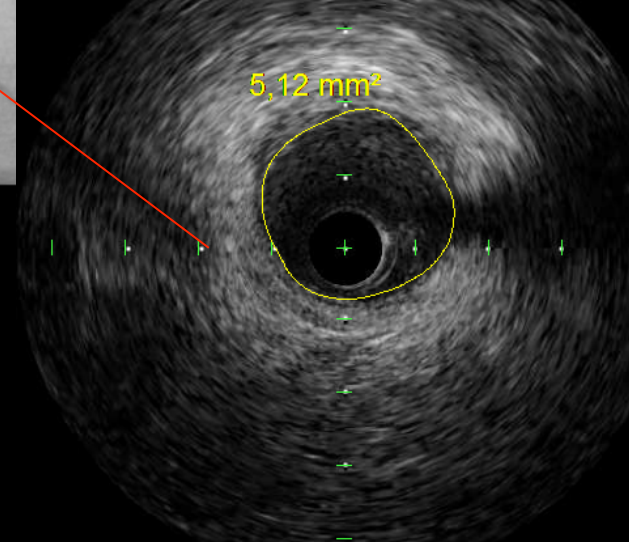
Series MainSeries:Post:LAD:RUN1(1-4448)
Frames 1..4448 by 1
Frame Time 51.03s
Frame 1515



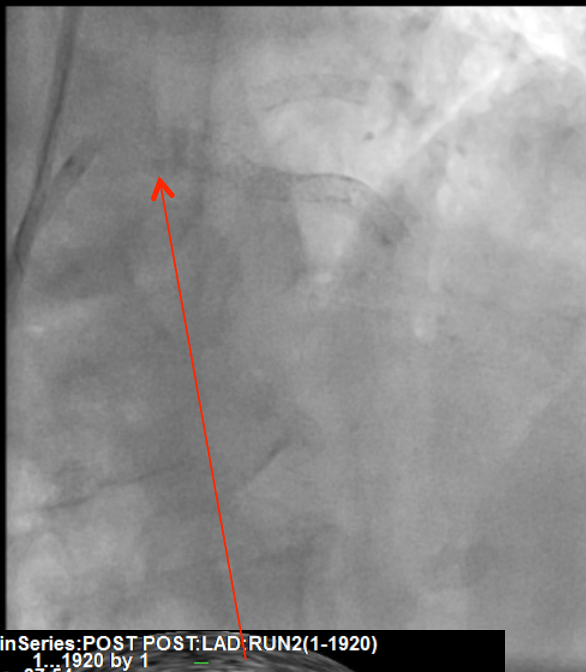
Series MainSeries:Post:LAD:RUN1(1-4448)
Frames 1..4448 by 1
Frame Time 122.52s
Frame 3640



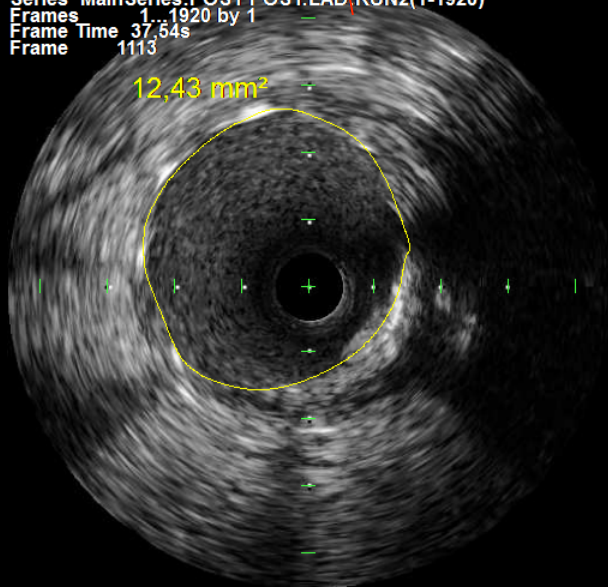
Series MainSeries:Post:LAD:RUN1(1-4448)
Frames 1..4448 by 1
Frame Time 35.72s
Frame 1060



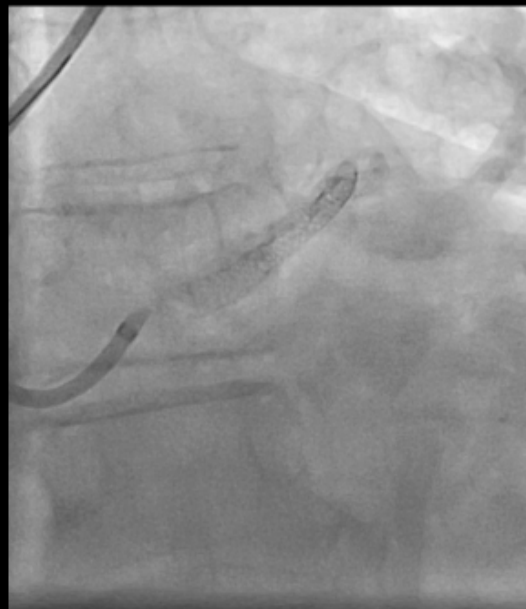
Dérivé



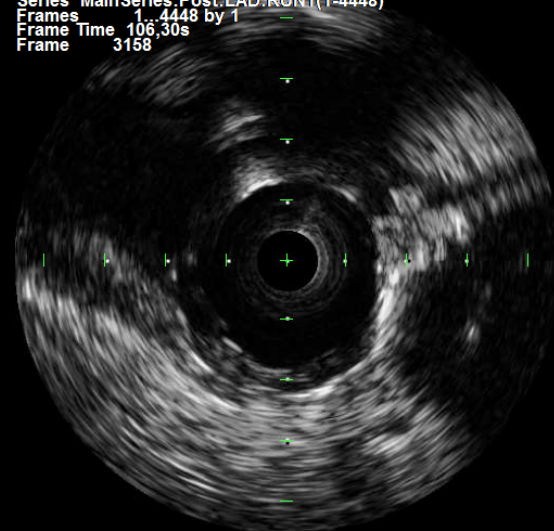
Series MainSeries:POST POST:LAD:RUN2(1-1920)
Frames 1, 1920 by 1
Frame Time 37,54s
Frame 1113



Dérivé



Series MainSeries:Post:LAD:RUN1(1-4448)
Frames 1, 4448 by 1
Frame Time 106,30s
Frame 3158



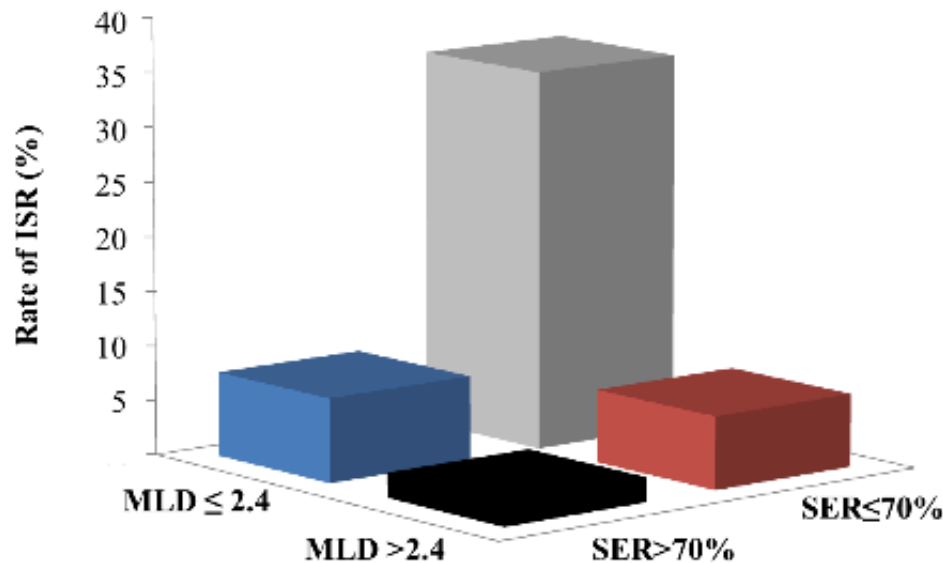
→ +50% MLA (8.5 mm²)

IVUS et CTO: facteurs prédictifs de resténose intrastent actif

126 CTO, DES, IVUS
11% de RIS à 9 mois, 6,3% de TVR

Facteurs indépendants de RIS:

- MLD post PCI: cutoff 2,4mm (AUC 0,762)
- Stent Expansion Ratio (SER)=CSA min/nominale cutoff 70%



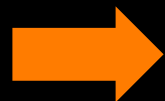
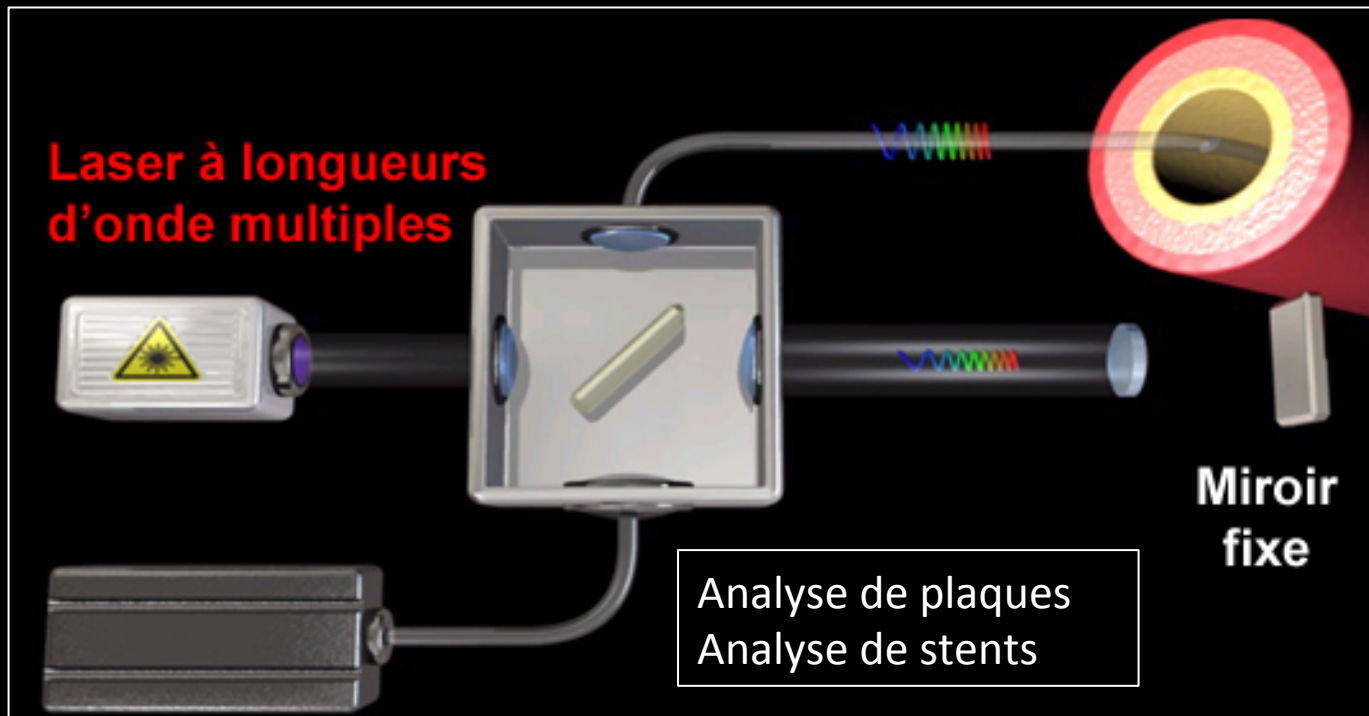
Si MLD < 2,4mm
Et SER < 70%
RIS **OR=23,3**

		MLD by QCA		Overall P by χ^2	Interaction P value
		≤2.4mm	>2.4mm		
SER by IVUS	≤70%	34.62% (9/26)	6.67% (2/30)	0.004	0.038
	>70%	7.69% (2/26)	2.27% (1/44)		

Nouvelle OCT : OFDI ou FD-OCT

2010

Optical Frequency Domain Imaging ou Frequency Domain - OCT



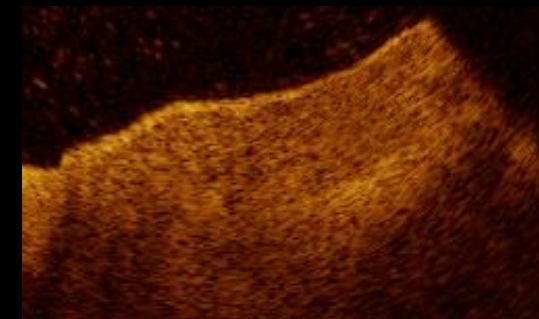
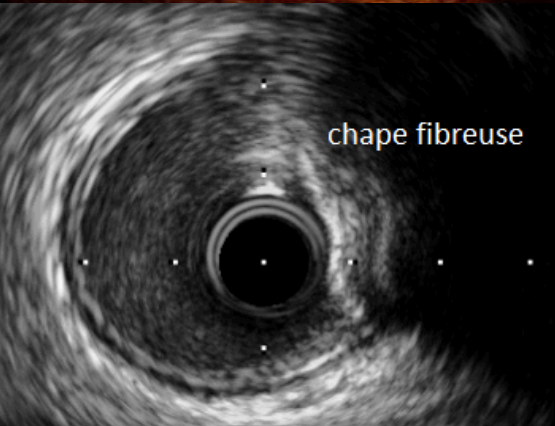
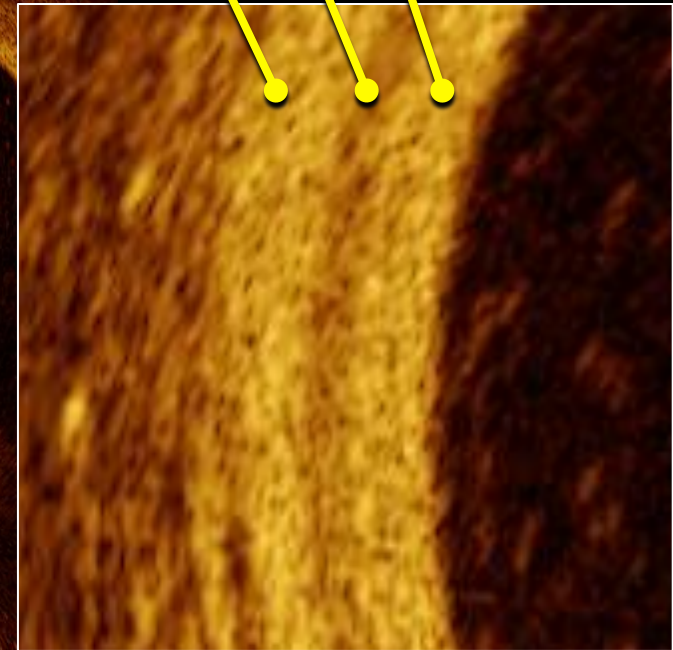
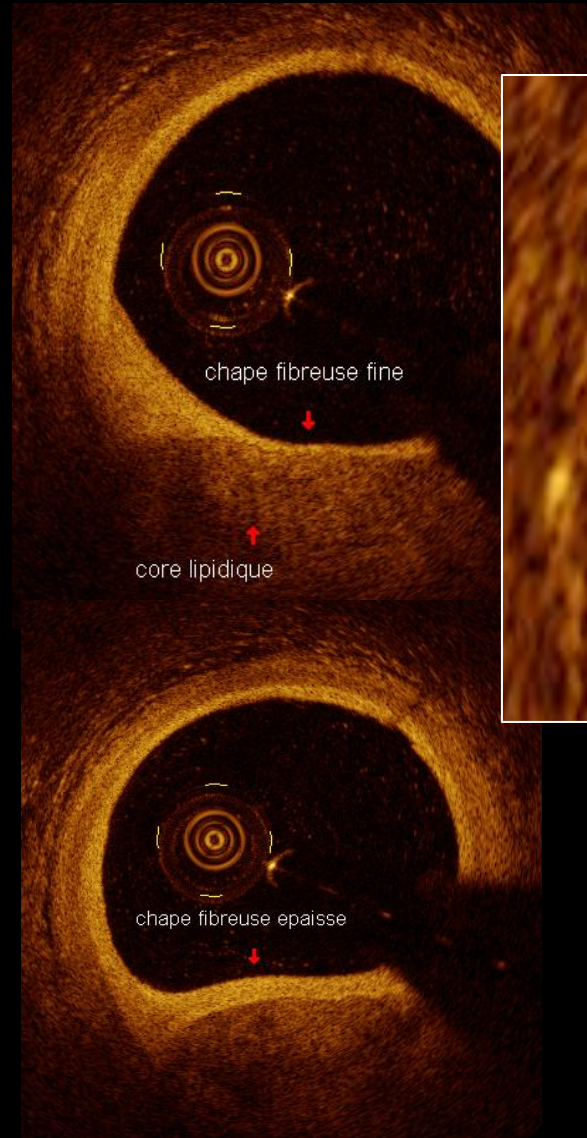
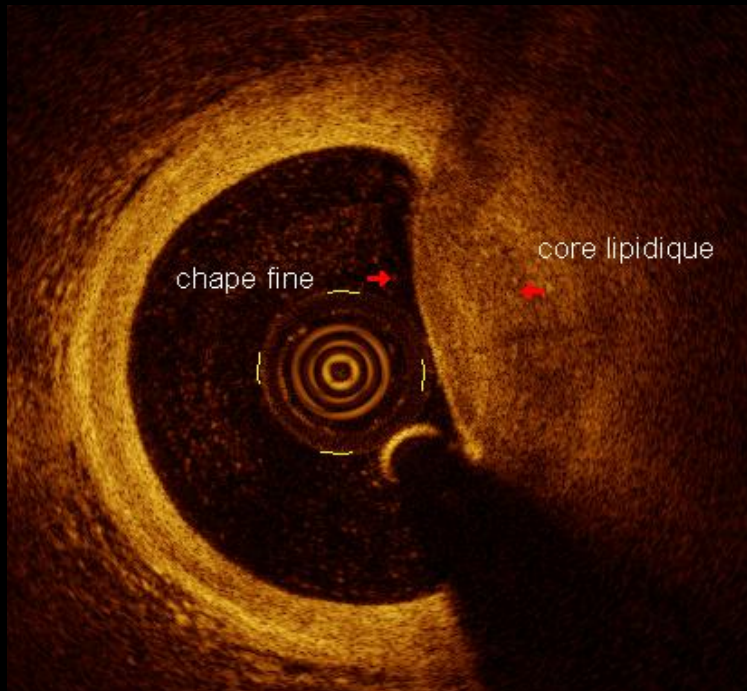
meilleure résolution : 10 microns
vitesse de retrait accélérée 20-40 mm/sec
ballon d'occlusion plus nécessaire

Analyse du signal par transformée de Fourier



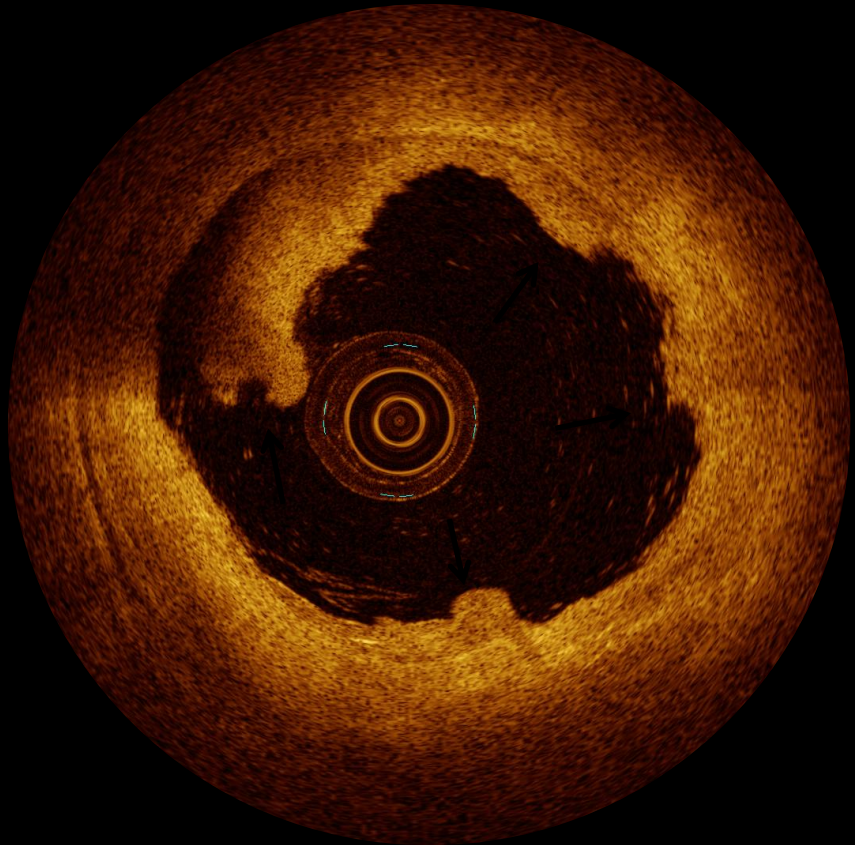
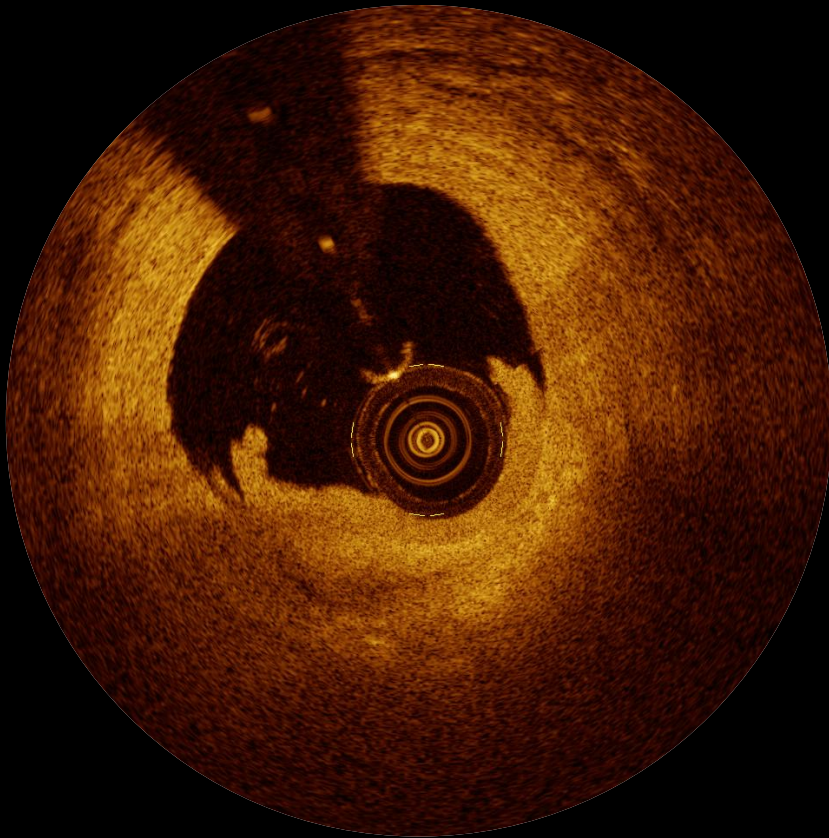
Les plaques lipidiques

Adventice
Media
Intima



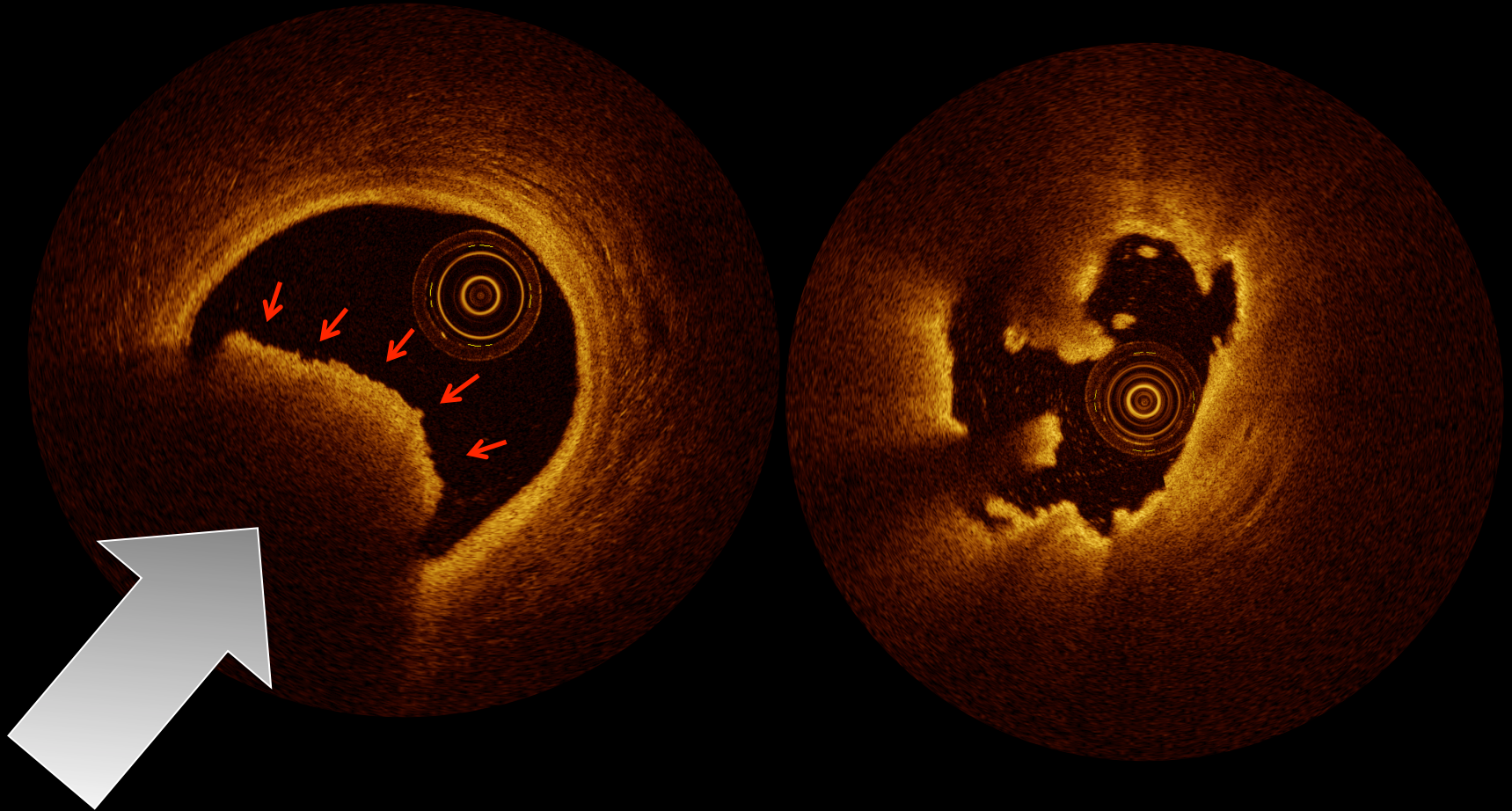
Imagerie OCT

Thrombus **blanc**



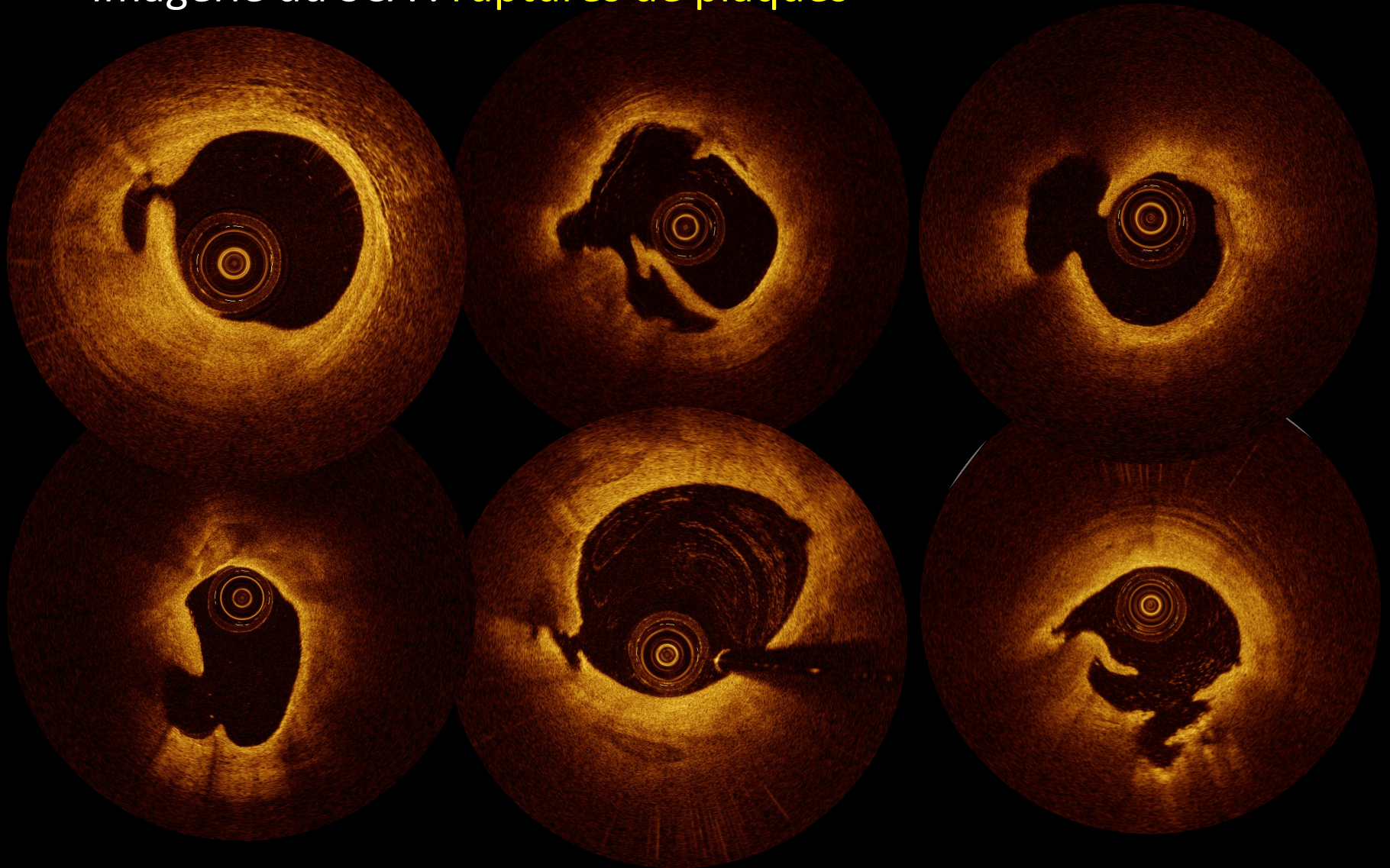
Imagerie OCT

Thrombus rouge



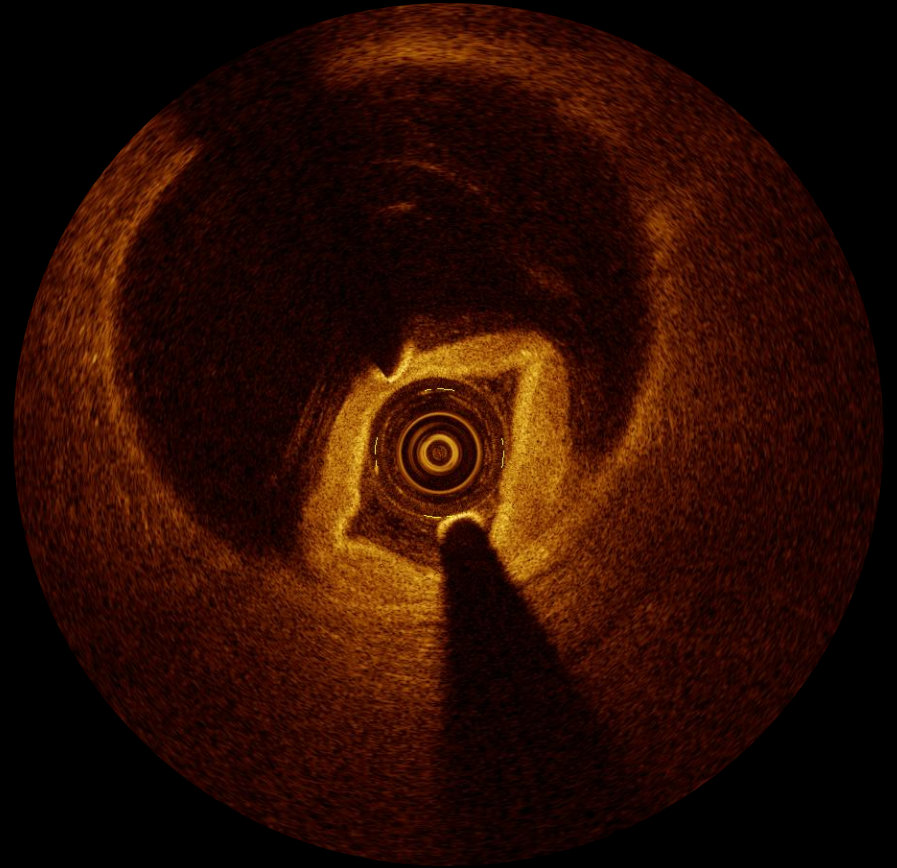
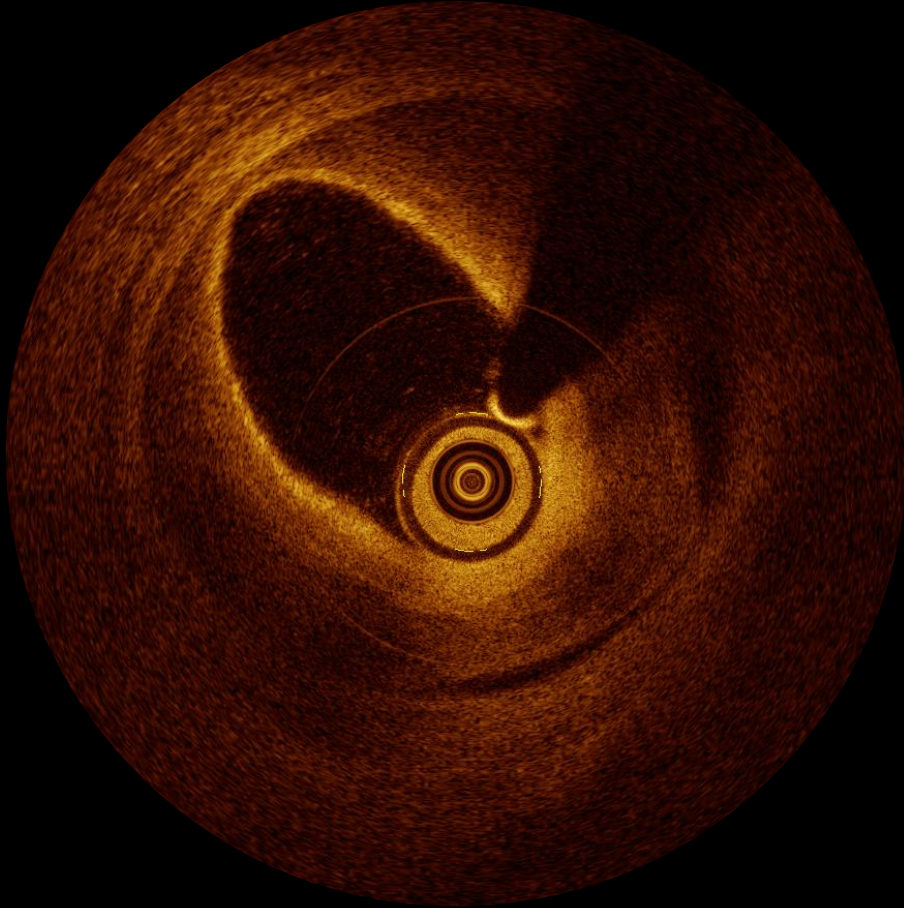
Imagerie OCT

Imagerie du SCA : ruptures de plaques



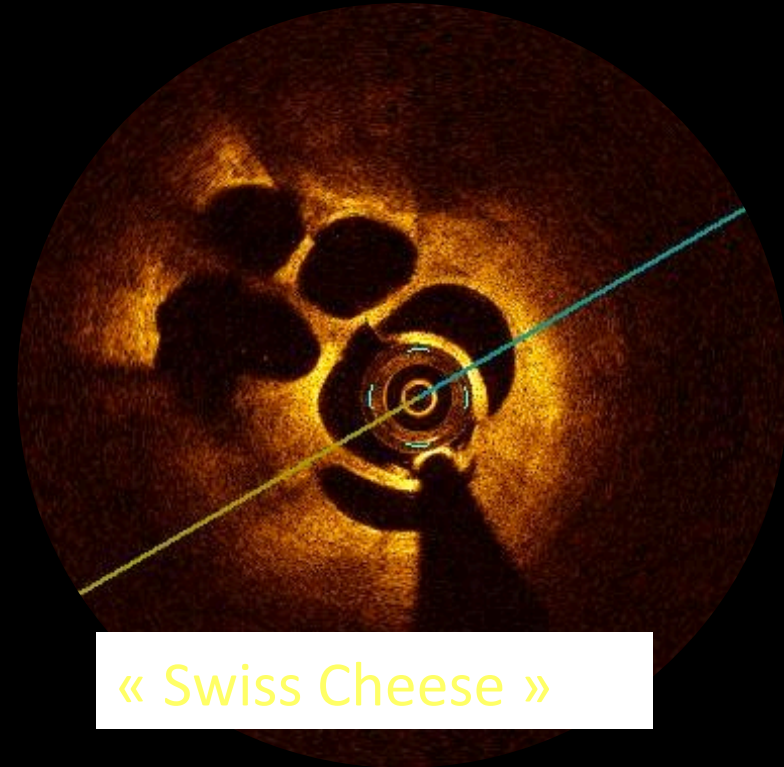
Imagerie OCT

Dissection coronaire **spontanée**

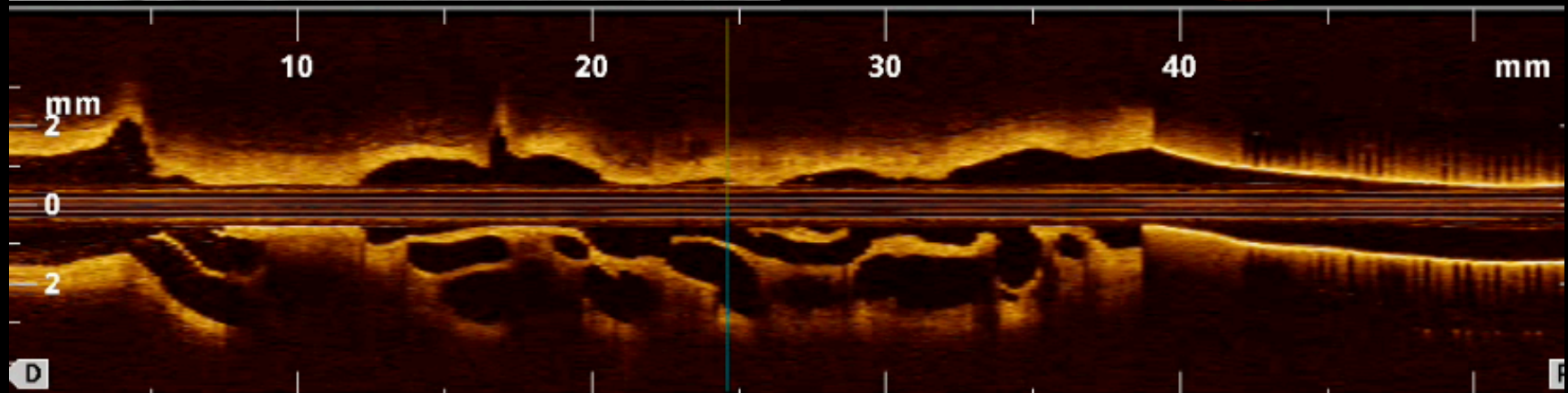


Imagerie OCT

Thrombus recanalisé

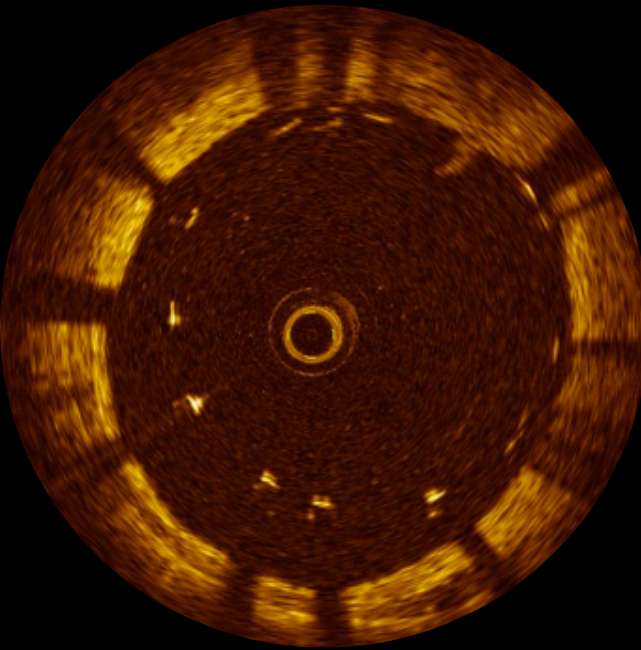


« Swiss Cheese »



Imagerie OCT

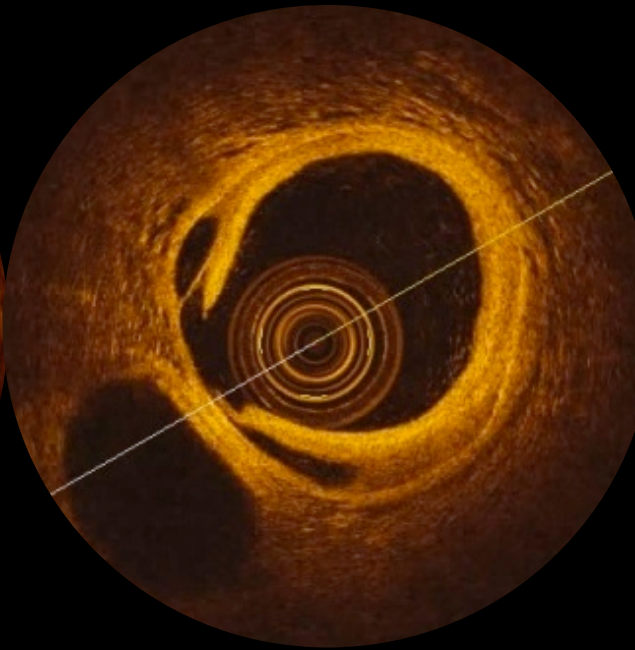
Post-stenting immédiat



Sous-déploiement

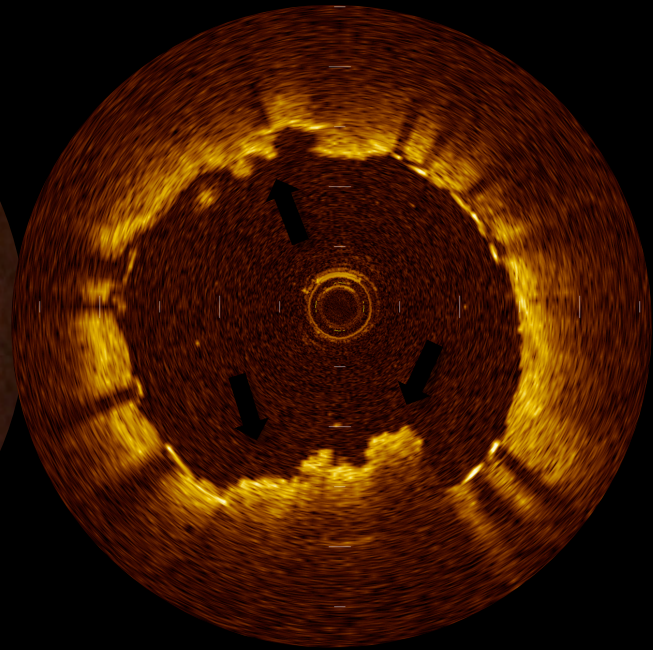
Malapposition si

$d > \text{épaisseur connue de la maille} + 10\mu\text{m}$



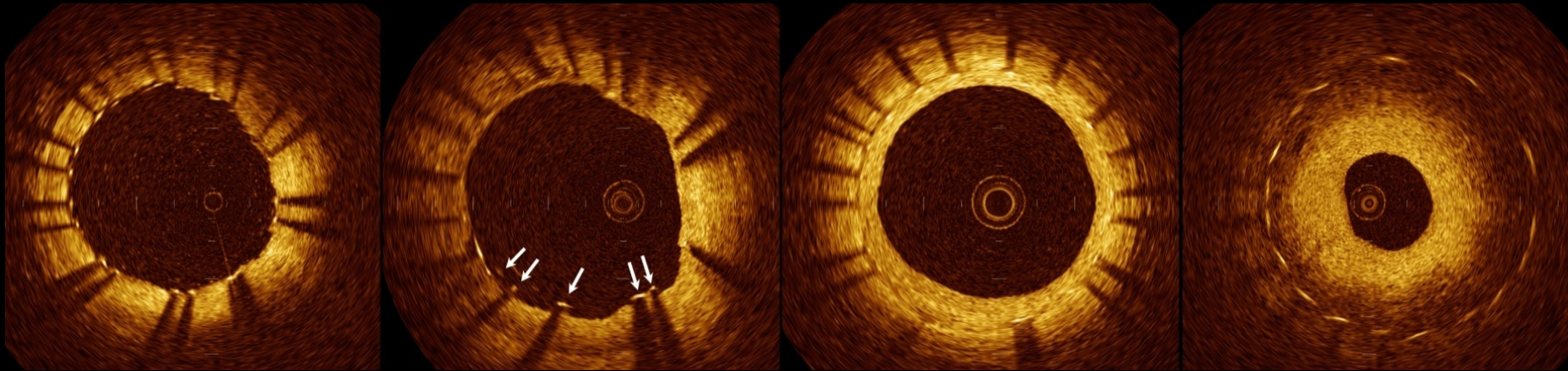
Dissection des bords

Protrusion
athéro-thrombotique



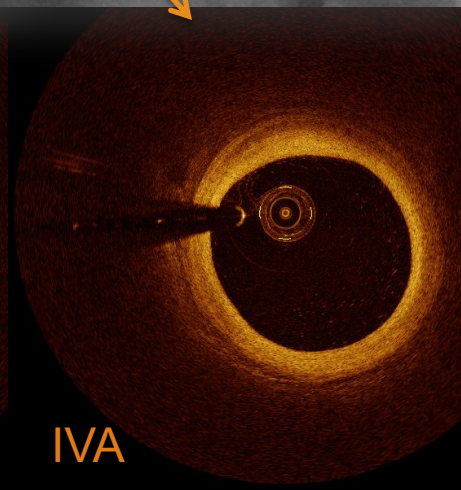
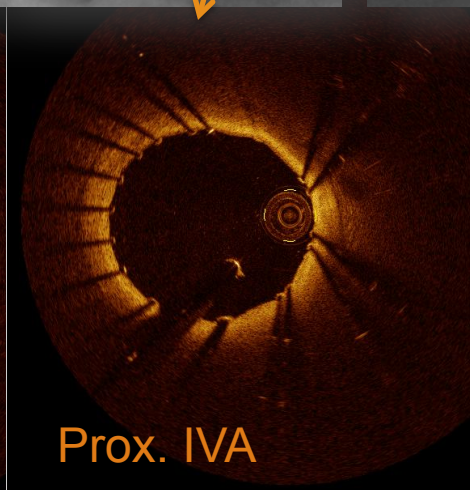
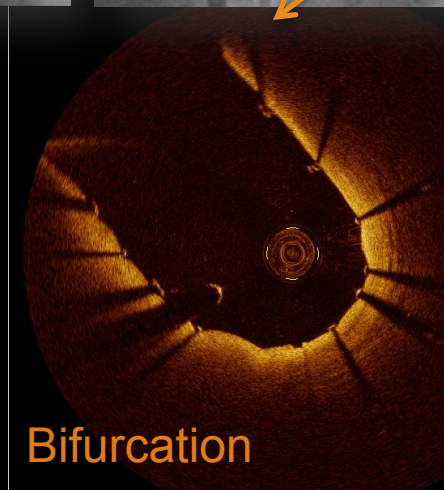
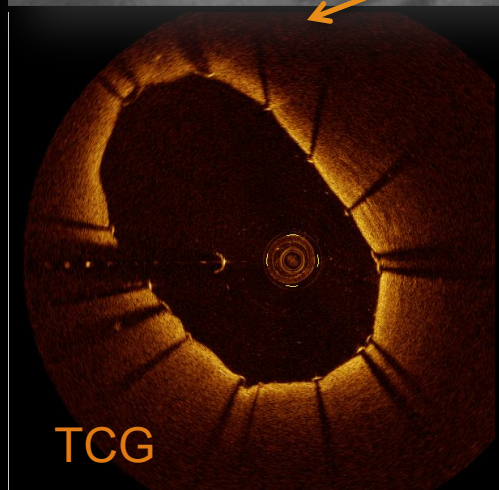
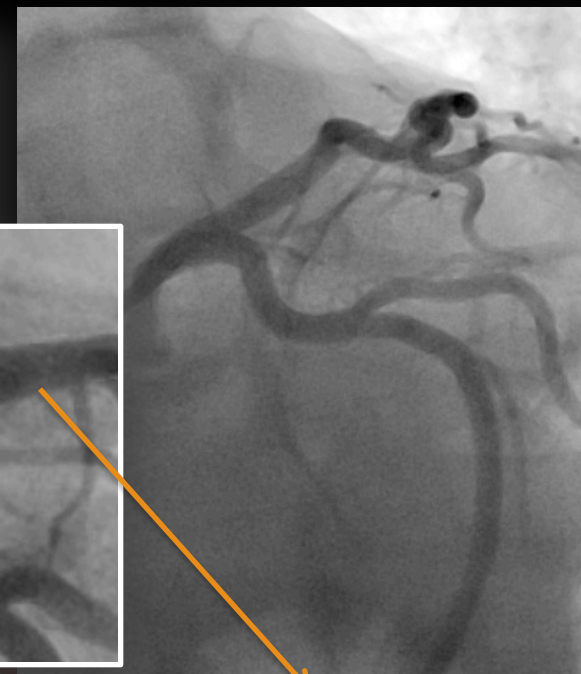
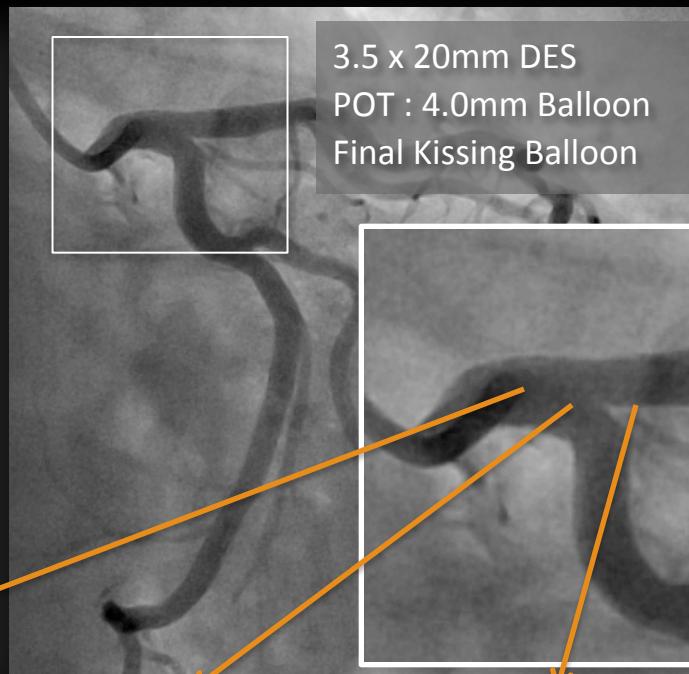
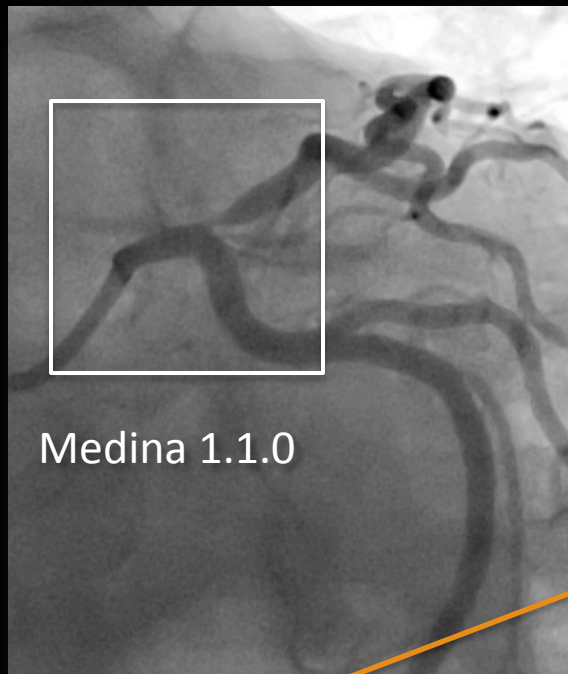
Imagerie OCT

Suivi des stents

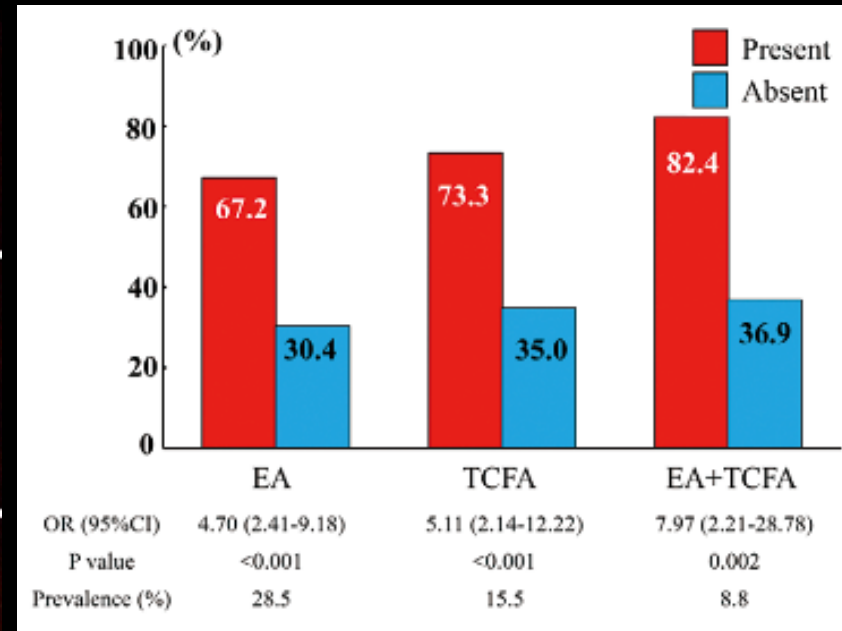
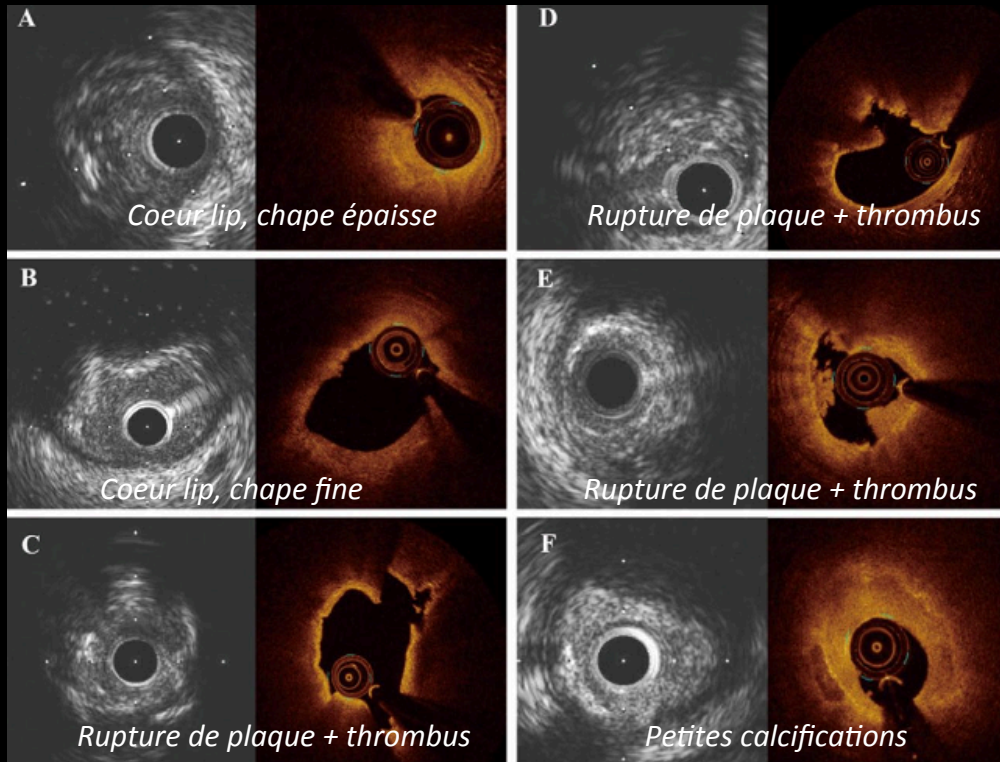


Imagerie OCT

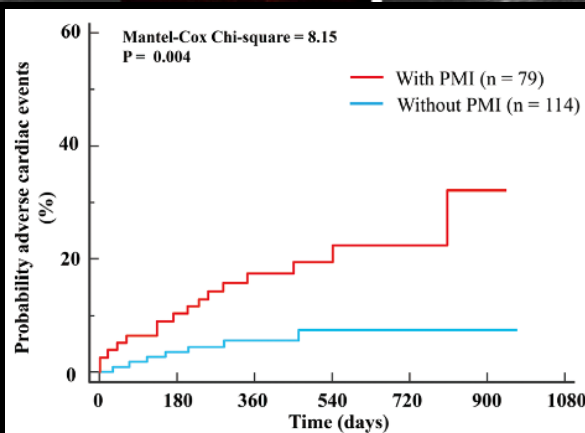
Procédures complexes



IVUS, OCT: analyse de plaque, prédicteur d'évènements



PostProcedural MI (Hs tropo+)
 EA= Echo-attenuated plaque
 TCFA= Thin-cap fibroatheroma



193 patients coronariens stables
 IVUS et OCT avant PCI

Post-PCI MI: MACES+

Facteurs prédictifs IVUS et OCT: EA+CTFA: **OR=8** de PMI

CONCLUSION: *FFR, IVUS, OCT*

ANALYSE FONCTIONNELLE: FFR, iFR, stratégie hybride+

ANALYSE MORPHOLOGIQUE : OCT, IVUS

Analyse de plaque

Recherche+

Aide à l'angioplastie: optimisation

Réduction des MACEs

ANALYSE MORPHOLOGIQUE ET FONCTIONNELLE : FFRct