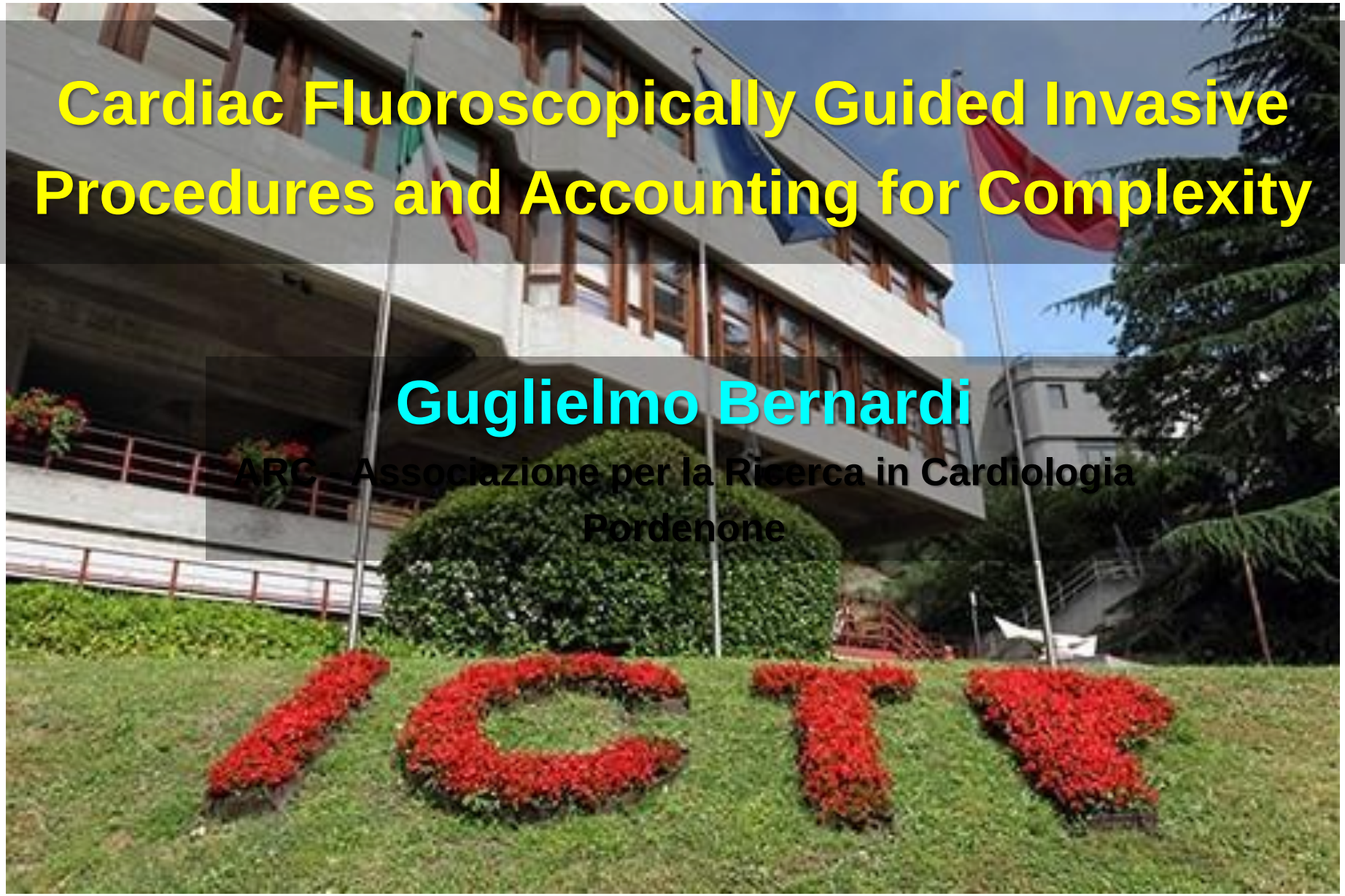
The Abdus Salam International Centre for Theoretical Physics
www.ictp.it

Joint ICTP-IAEA Workshop on Establishment and Utilization of Diagnostic Reference Levels in Medical Imaging
18-22 November 2019, Trieste, Italy

IAEA International Atomic Energy Agency
Atoms for Peace

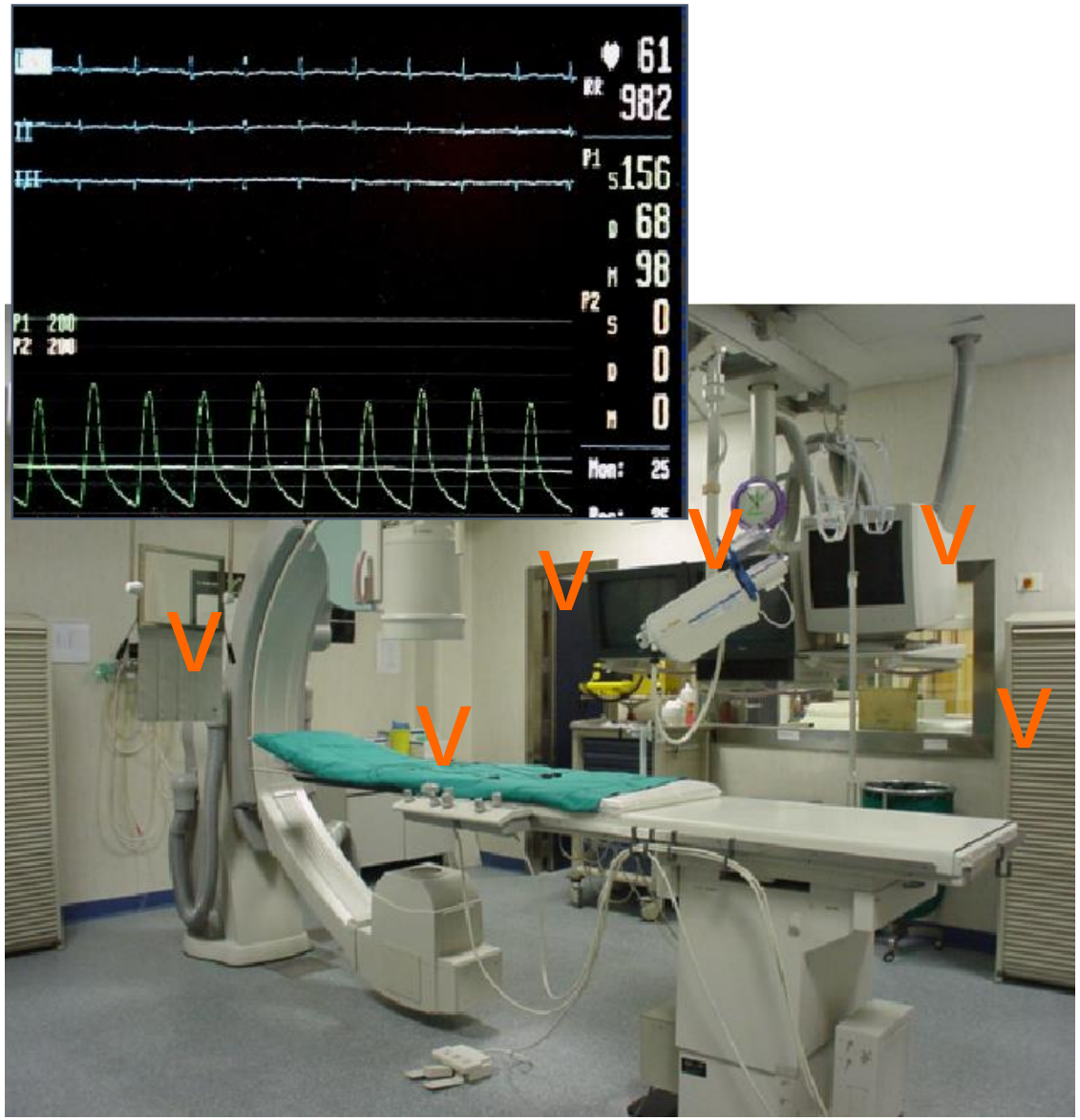
Cardiac Fluoroscopically Guided Invasive Procedures and Accounting for Complexity



Guglielmo Bernardi

ARC - Associazione per la Ricerca in Cardiologia
Pordenone

Catheterization suite



Angiografic machine

protections

injector

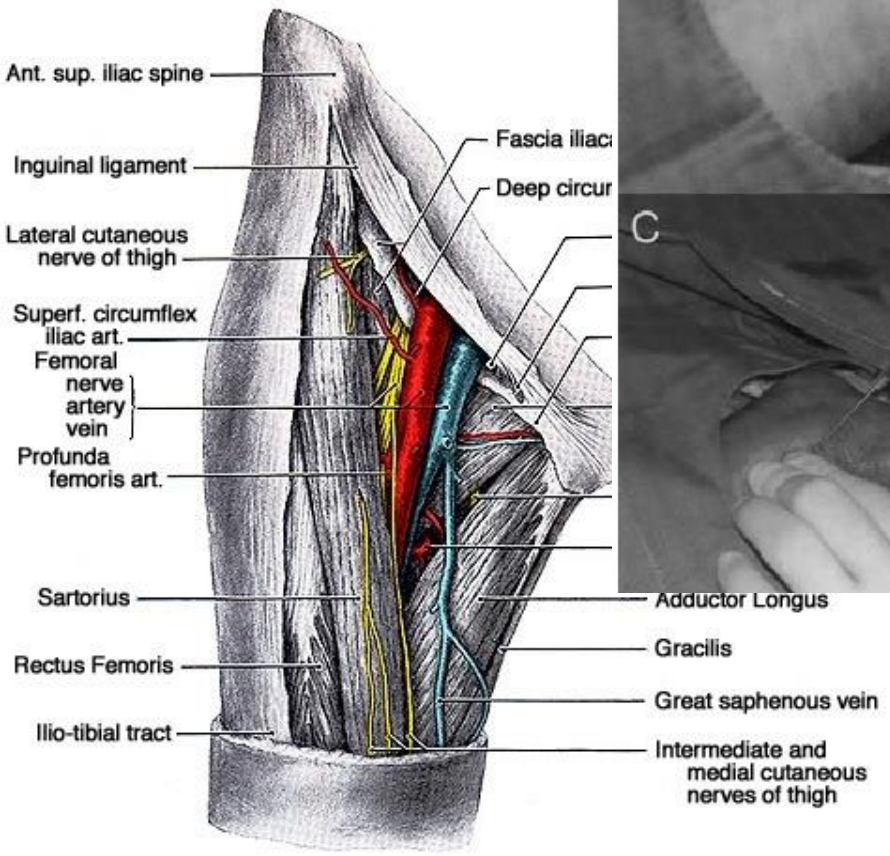
monitors

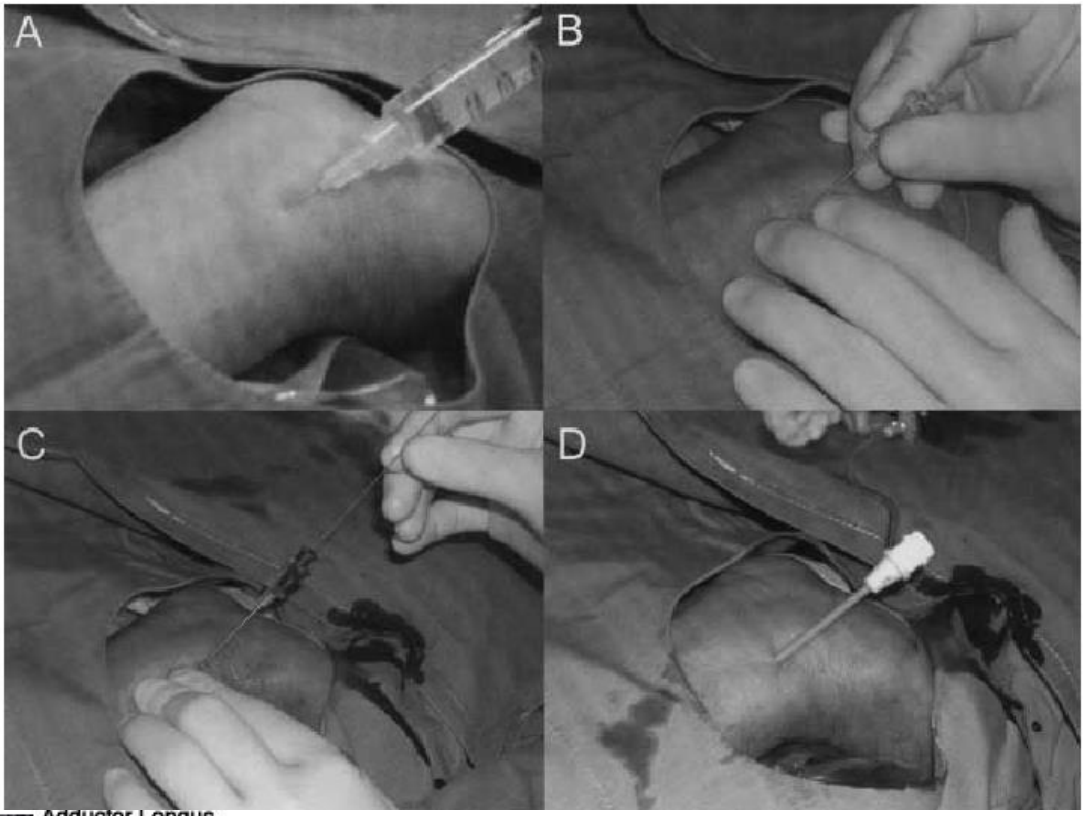
defibrillator

drugs

Vascular access

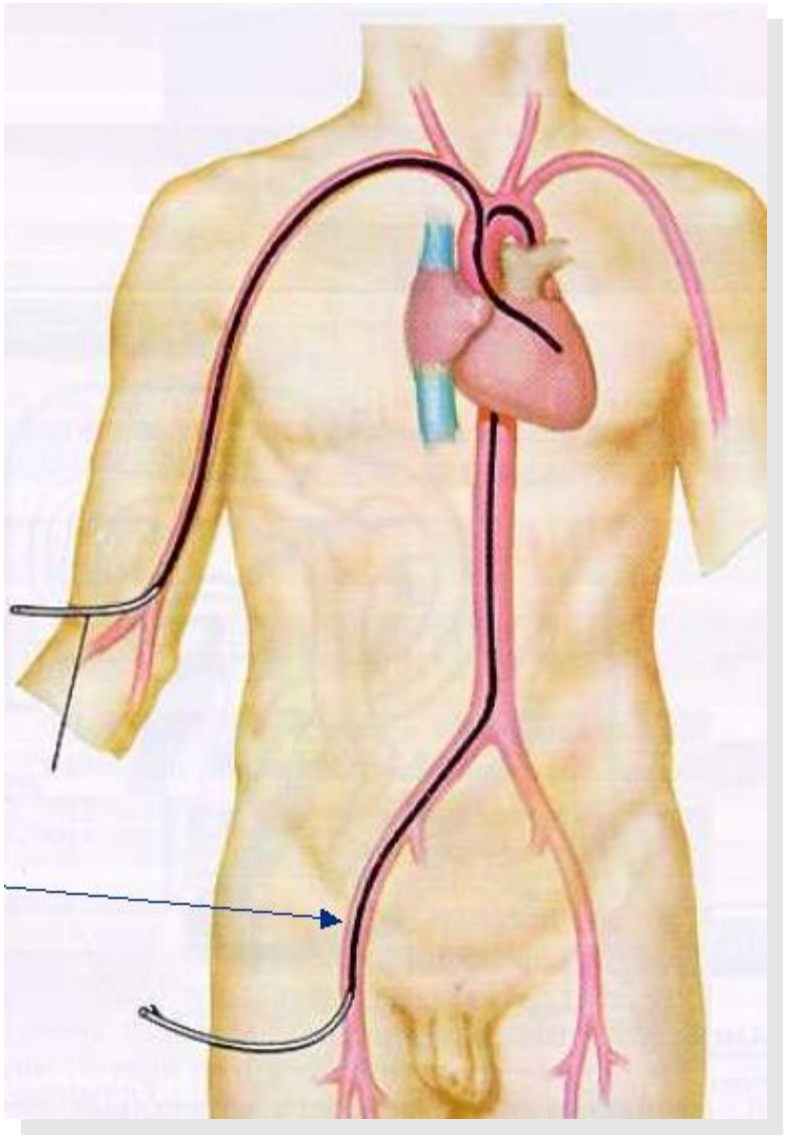
femoral

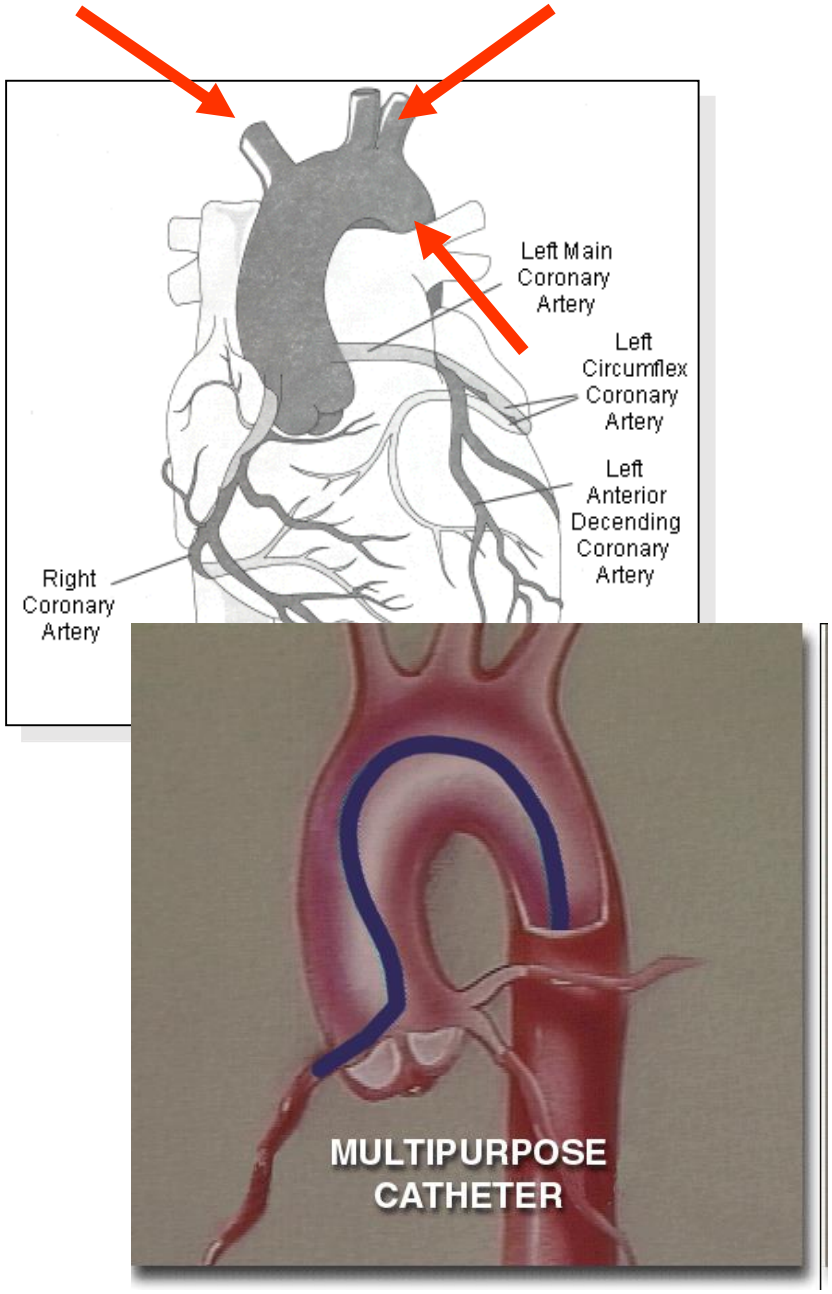




radial

Vascular access





Interventional cardiology

- ✓ Coronary angiography
- ✓ Adjunctive imaging techniques (IVUS, OCT)
- ✓ Coronary angioplasty (PTCA-PCI)
- ✓ Treatment of “structural” Heart Diseases
  - ✓ Valvuloplasty (dilatation of cardiac valves)
    - ✓ aortic, mitral, tricuspid, pulmonary
  - ✓ Valve implantation
  - ✓ Mitral repair
  - ✓ Atrial/Ventricular septal defect occlusion
  - ✓ Left atrial appendage occlusion
  - ✓ Fistulas occlusion

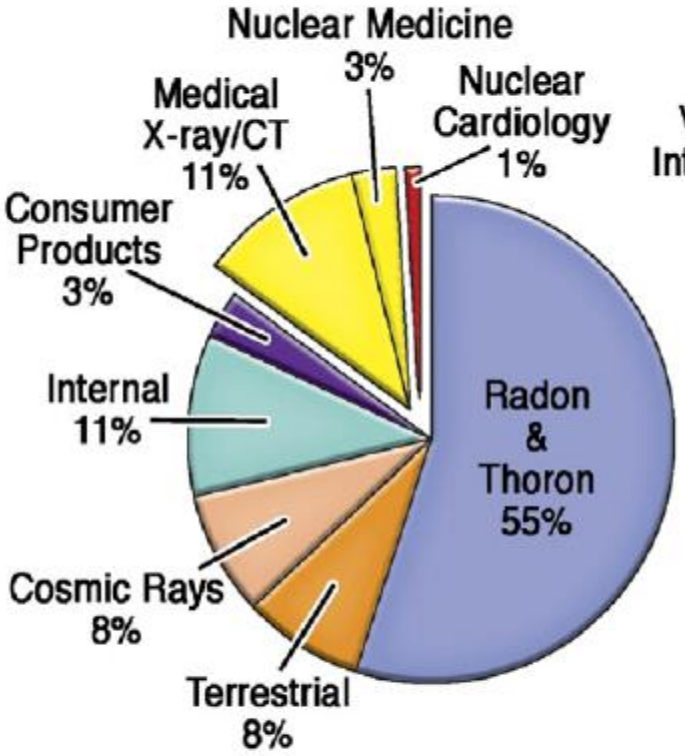
Electrophysiology

diagnostic & interventional

- ✓ EP diagnostic studies
- ✓ Pacemaker implantation
- ✓ Automatic implantable cardioverter defibrillator (AICD)
- ✓ Arrhythmias ablation
  - ✓ Accessory pathways
  - ✓ Atrial fibrillation/flutter
  - ✓ Ventricular tachycardia/VPB

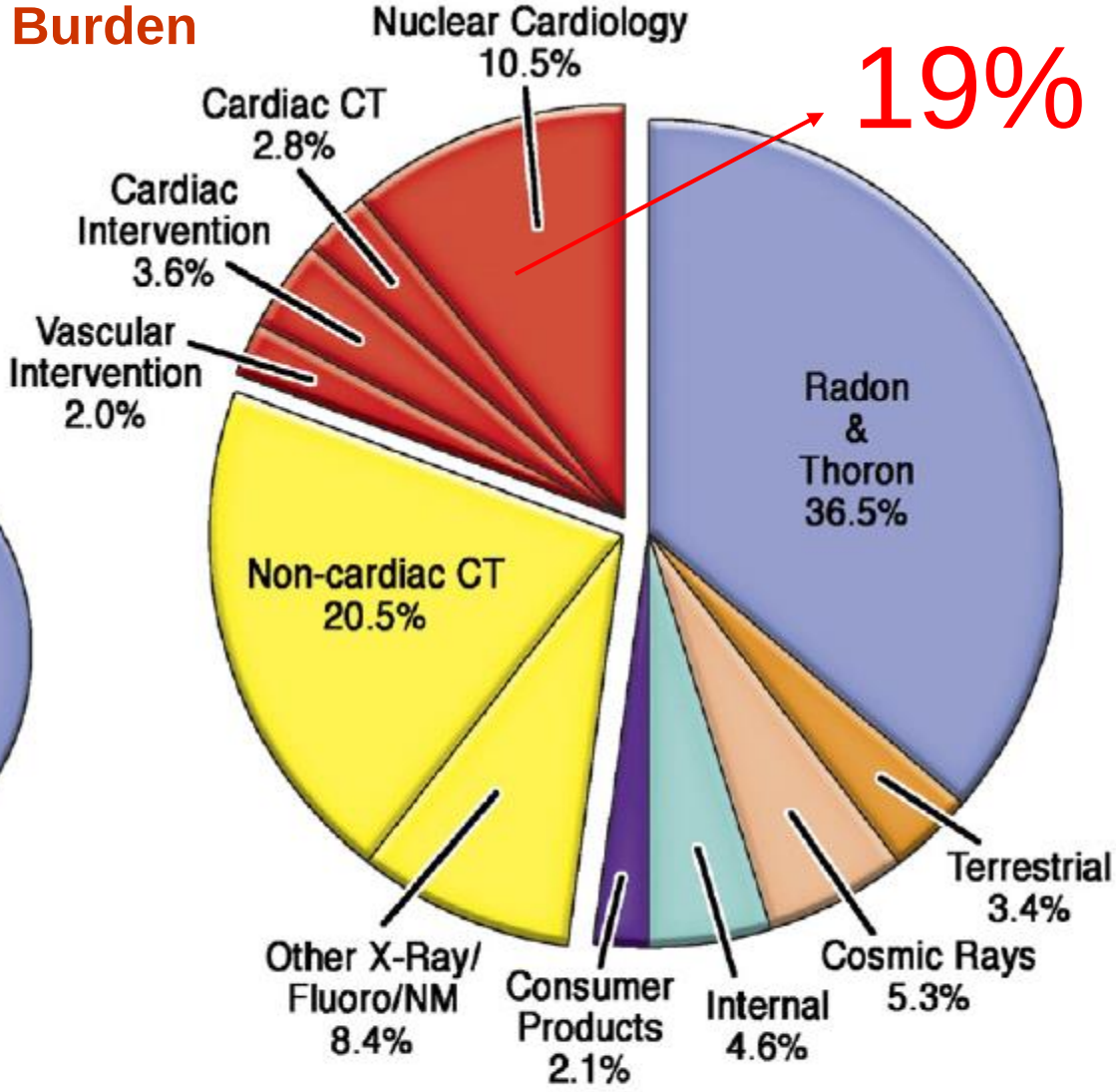
The Increasing U.S. Radiation Burden

Einstein AJ, JACC 2012; 59:553



1980-1982

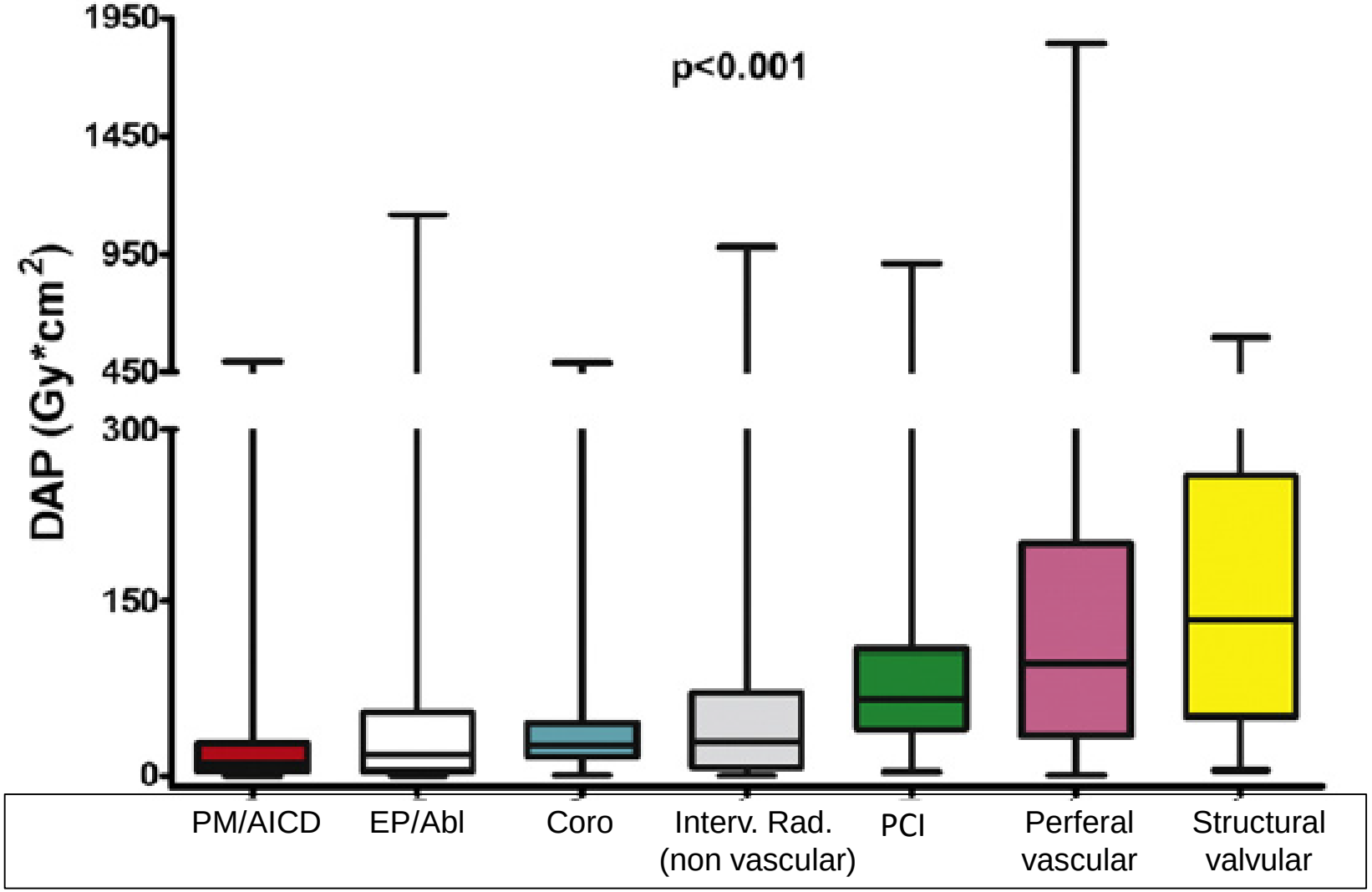
Medical Radiation: 0.53 mSv per capita per year
Non-medical Radiation: 3.1 mSv per capita per year
Cardiovascular Radiation Collective Effective Dose: 6,700 person-Sv
Medical Radiation Collective Effective Dose: 123,000 person-Sv



2006

Medical Radiation: 3.0 mSv per capita per year
Non-medical Radiation: 3.2 mSv per capita per year
Cardiovascular Radiation Collective Effective Dose: 356,000 person-Sv
Medical Radiation Collective Effective Dose: 899,000 person-Sv

Dose area product in different fluoroscopically guided percutaneous procedures



Sciahbasi A, Internat J Cardiol 2017;240:92

Interventional cardiology

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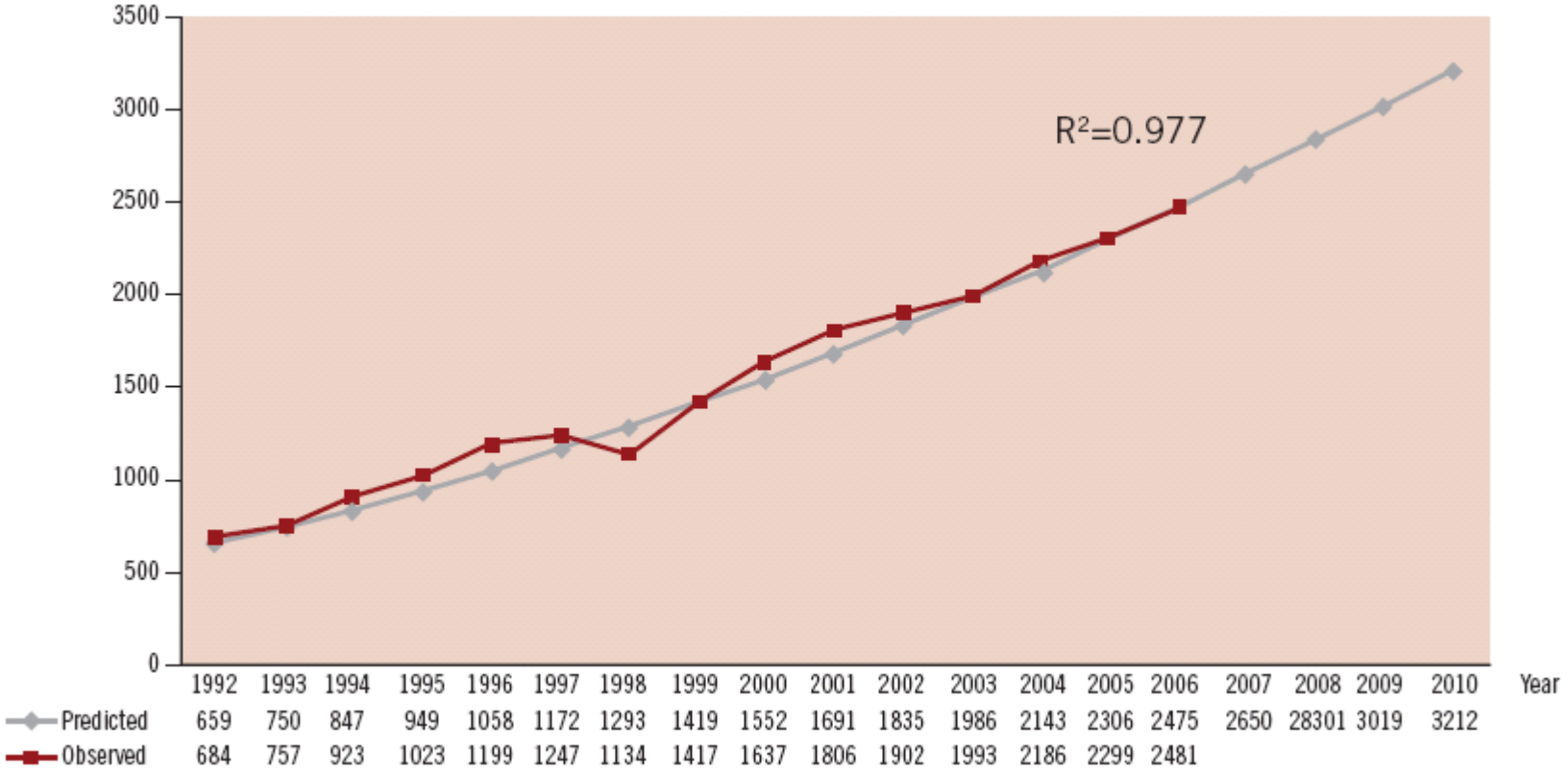
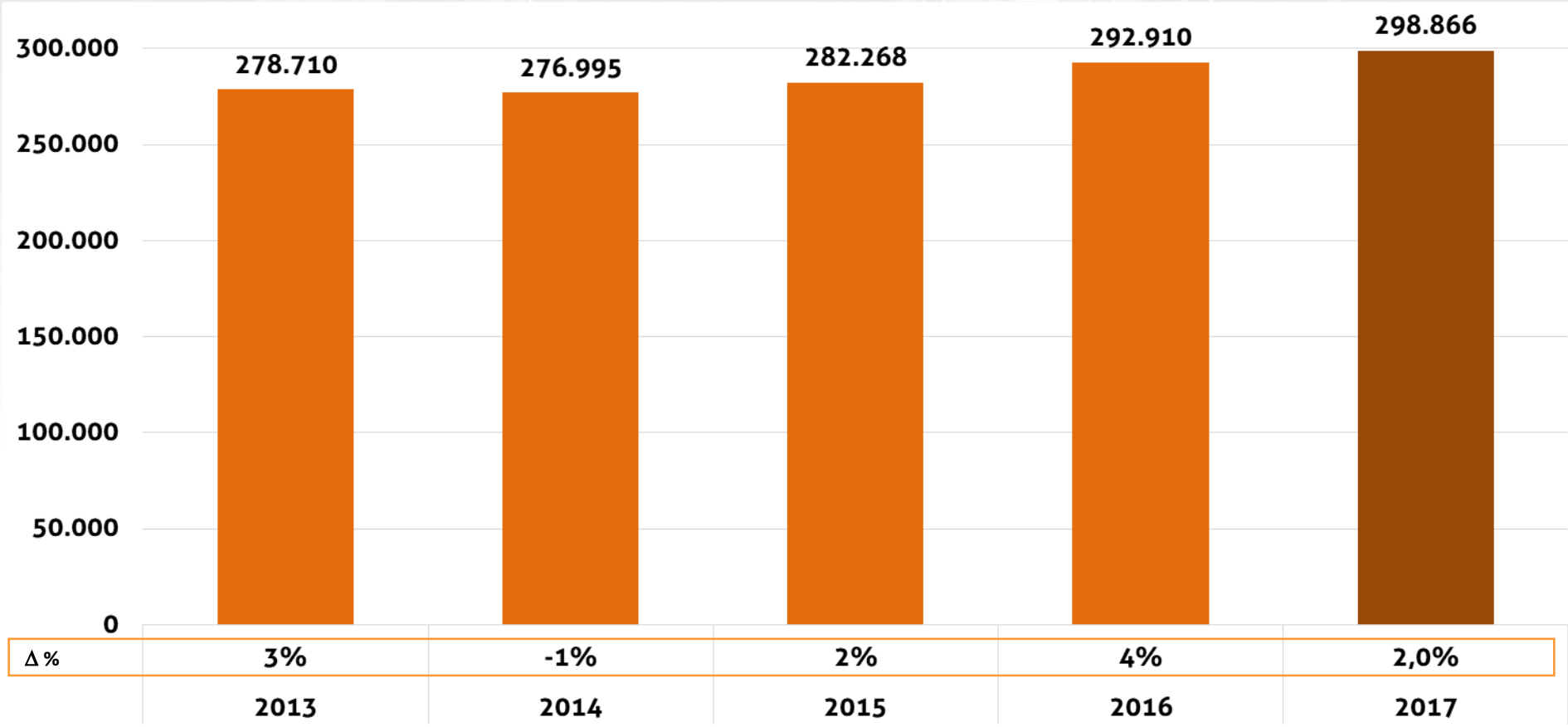
Coronary angiography Europe

Coronary angiography: the most performed angiographic procedure in the Western world. The second in-hospital procedure in USA



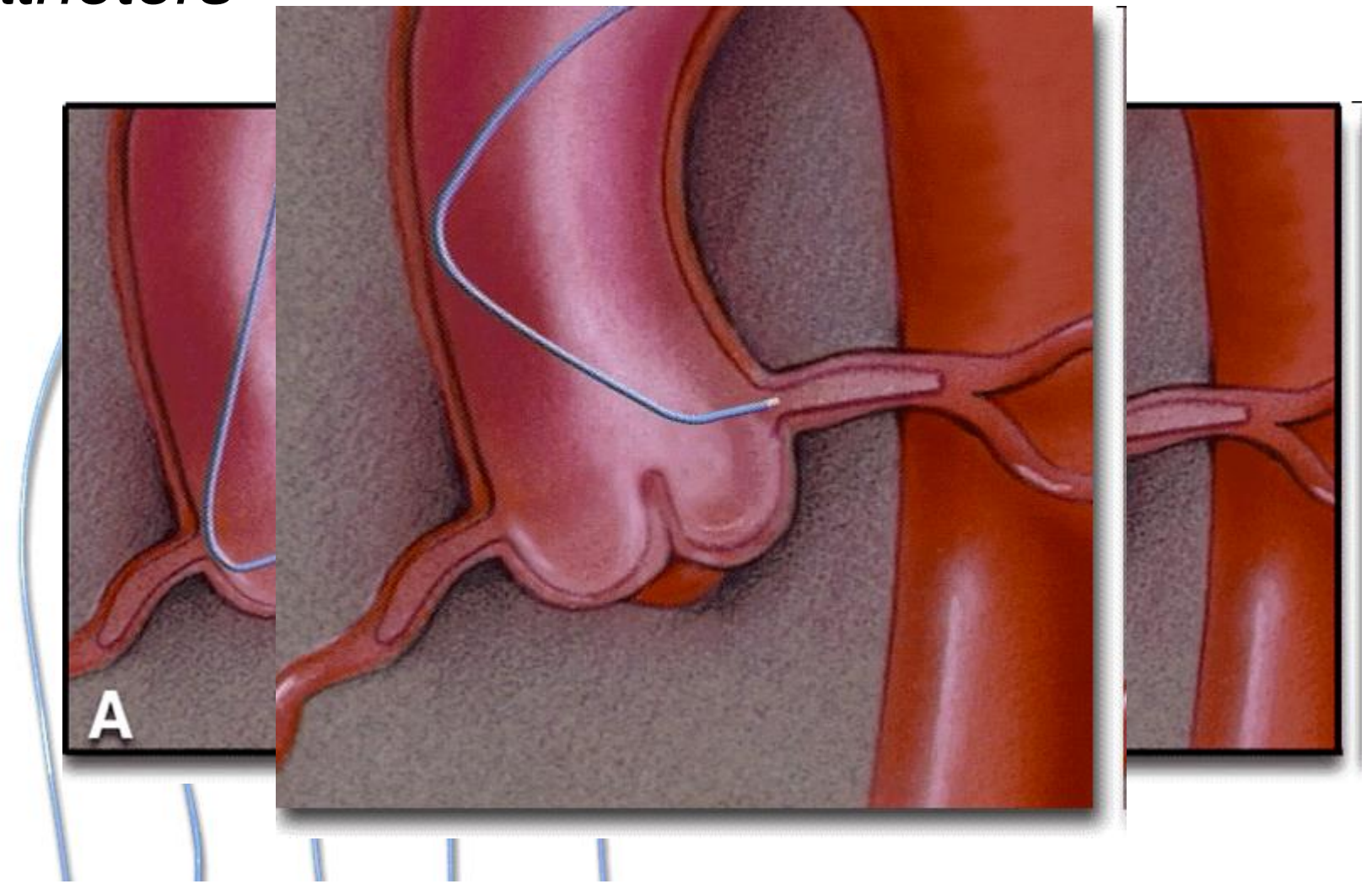
Moschovitis A, Eurointervention 2010;6:189

ESAMI DIAGNOSTICI – CORONAROGRAFIE
ITALIA SERIE STORICA

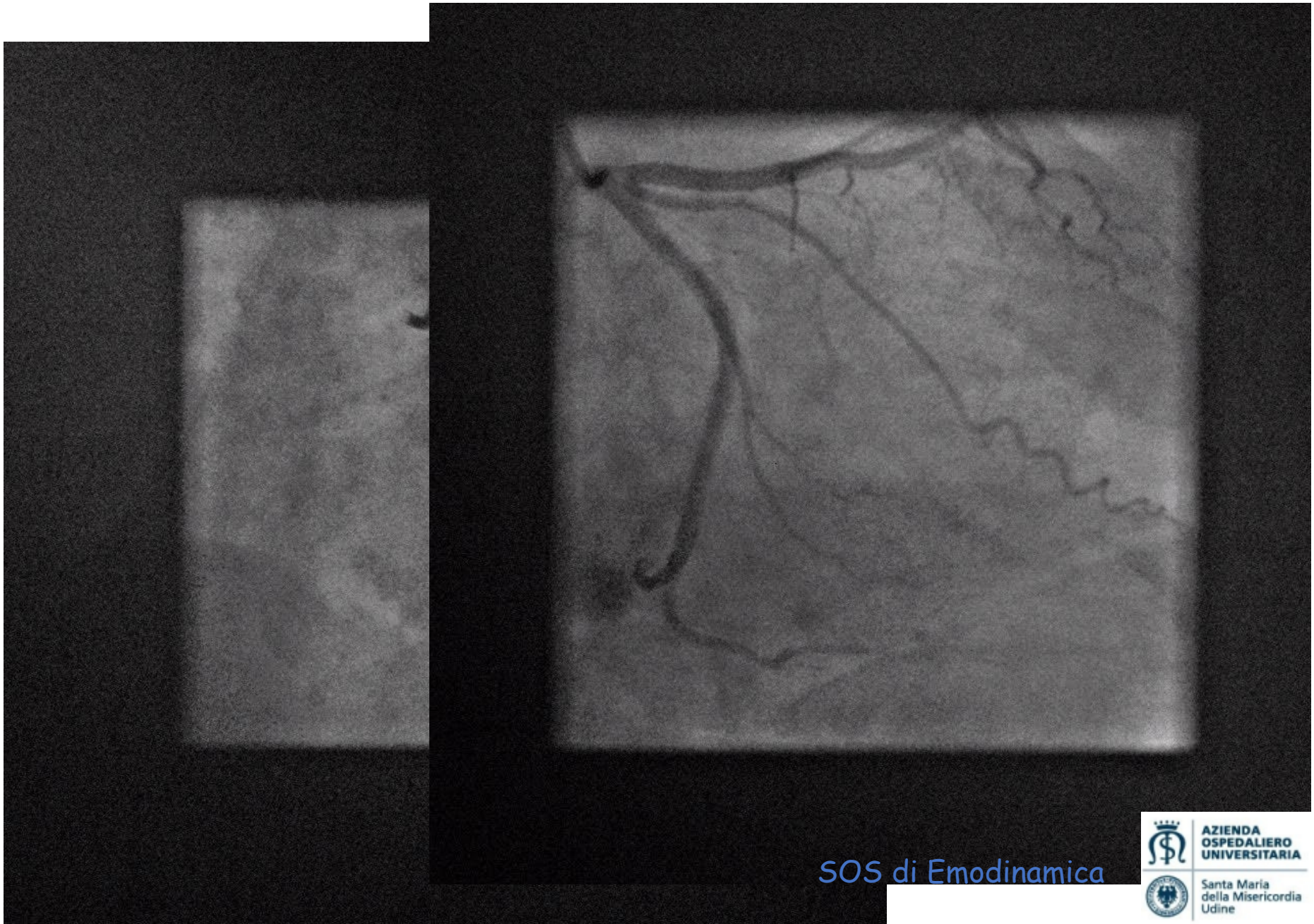


Coronary Angiopraphy

catheters



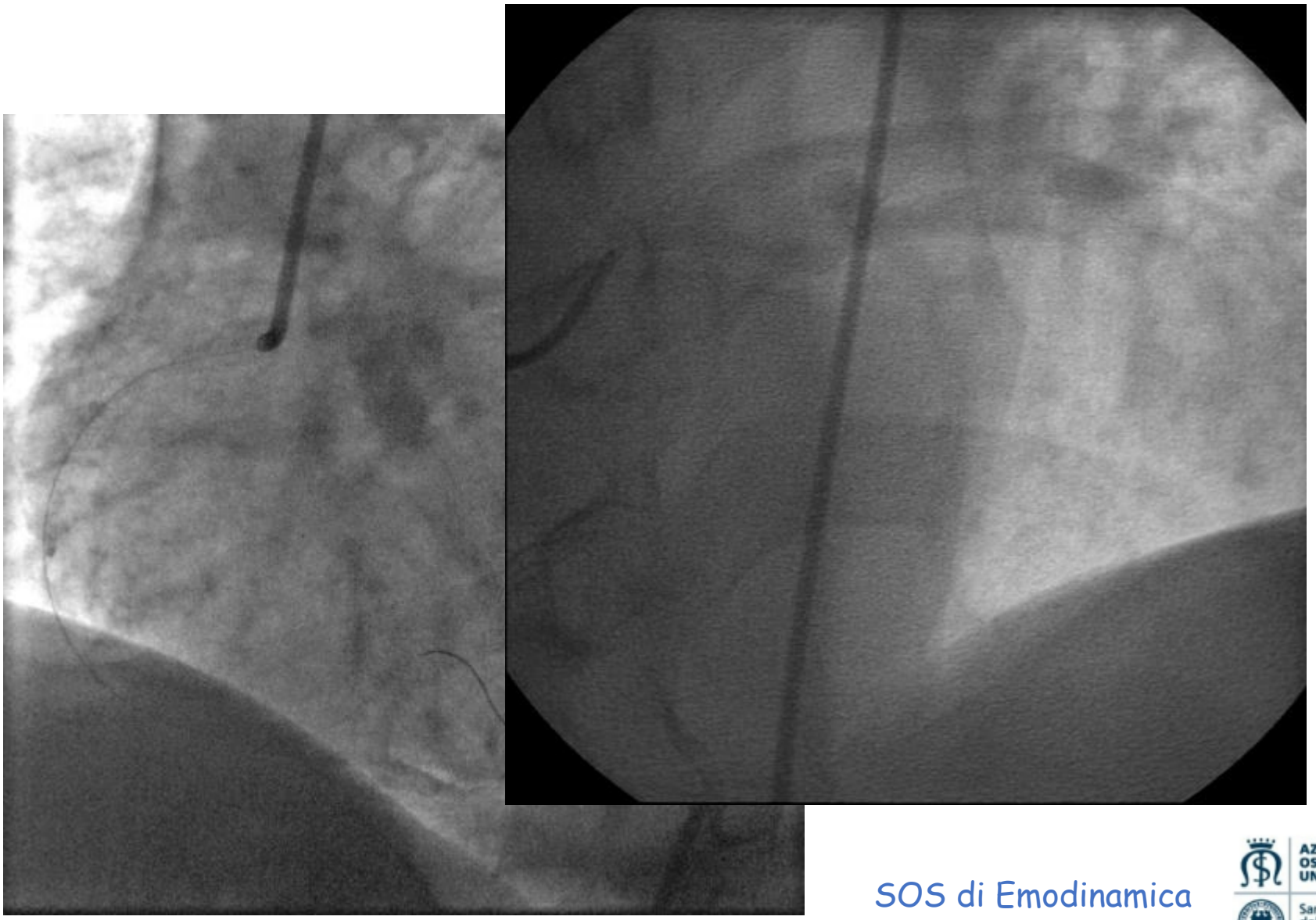
Coronary Angiopraphy *injection of iodine contrast*



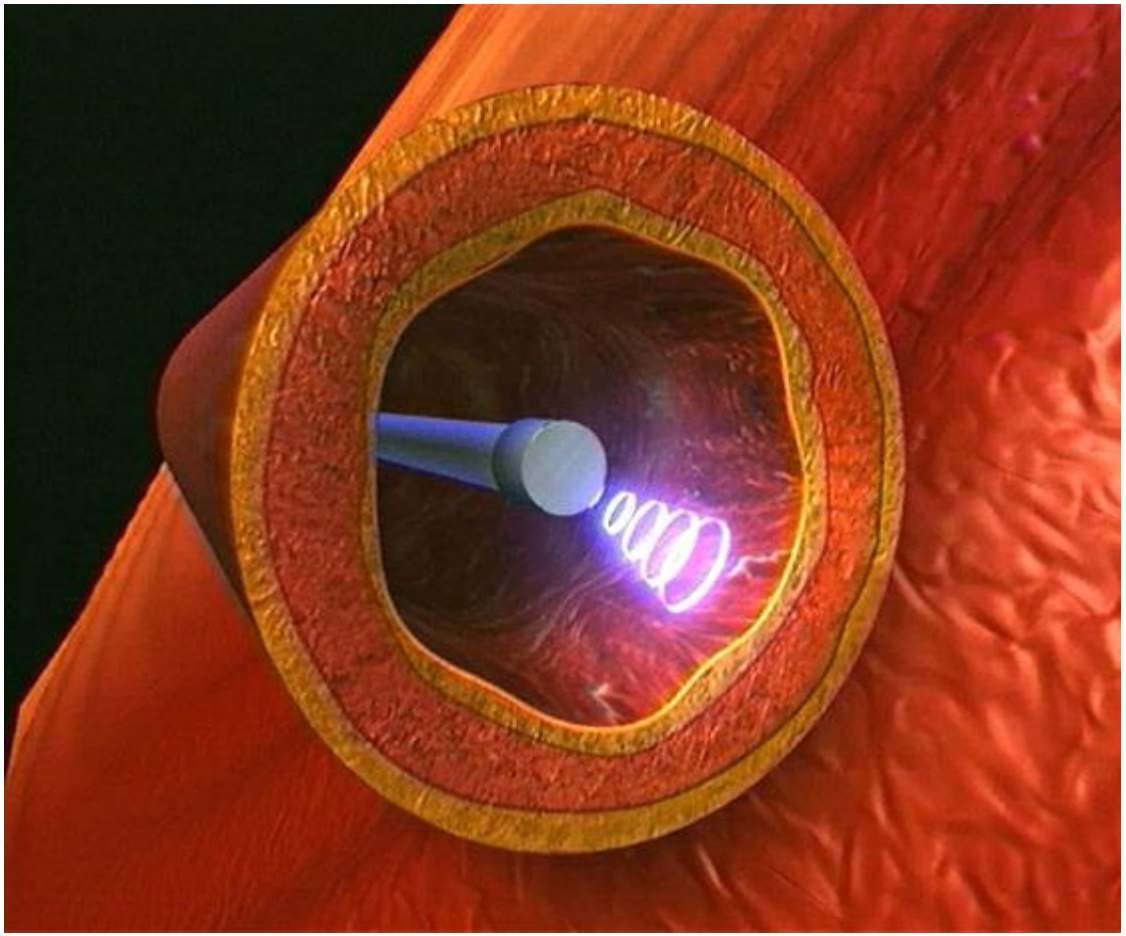
SOS di Emodinamica

AZIENDA OSPEDALIERO UNIVERSITARIA
Santa Maria della Misericordia Udine

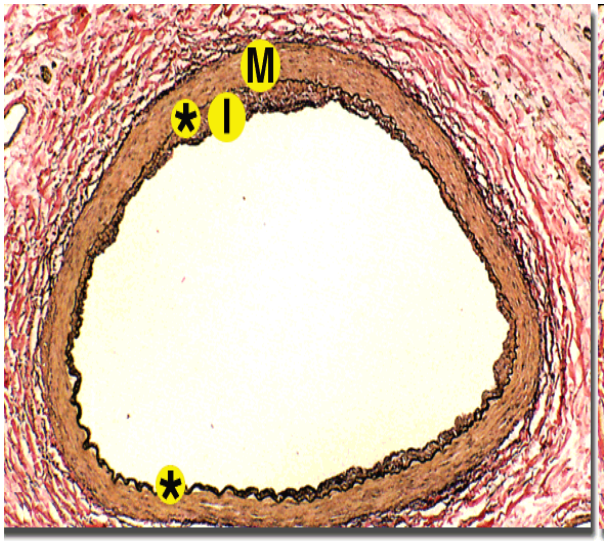
Coronary Angiopraphy

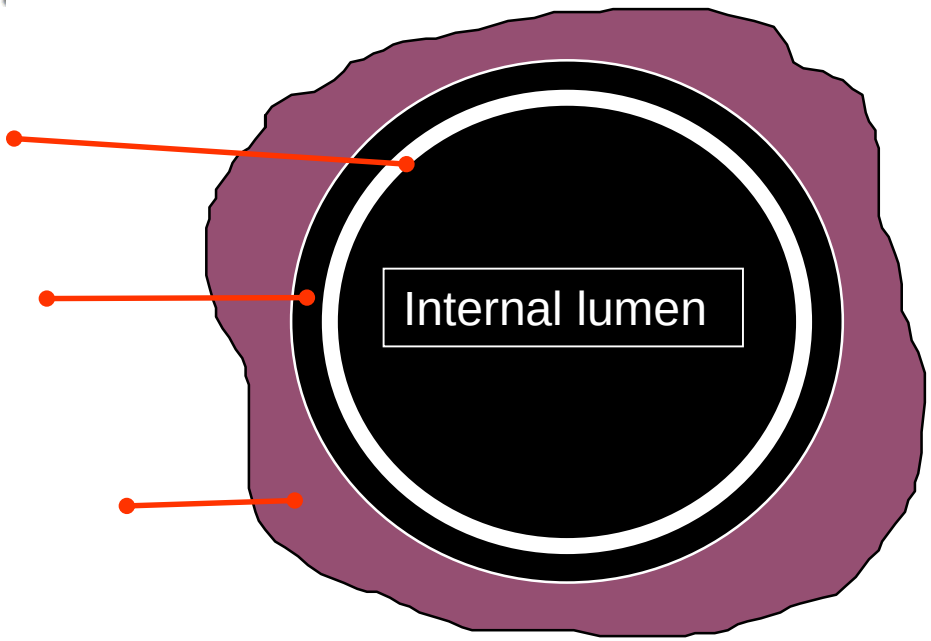


Intravascular ultrasounds (IVUS)

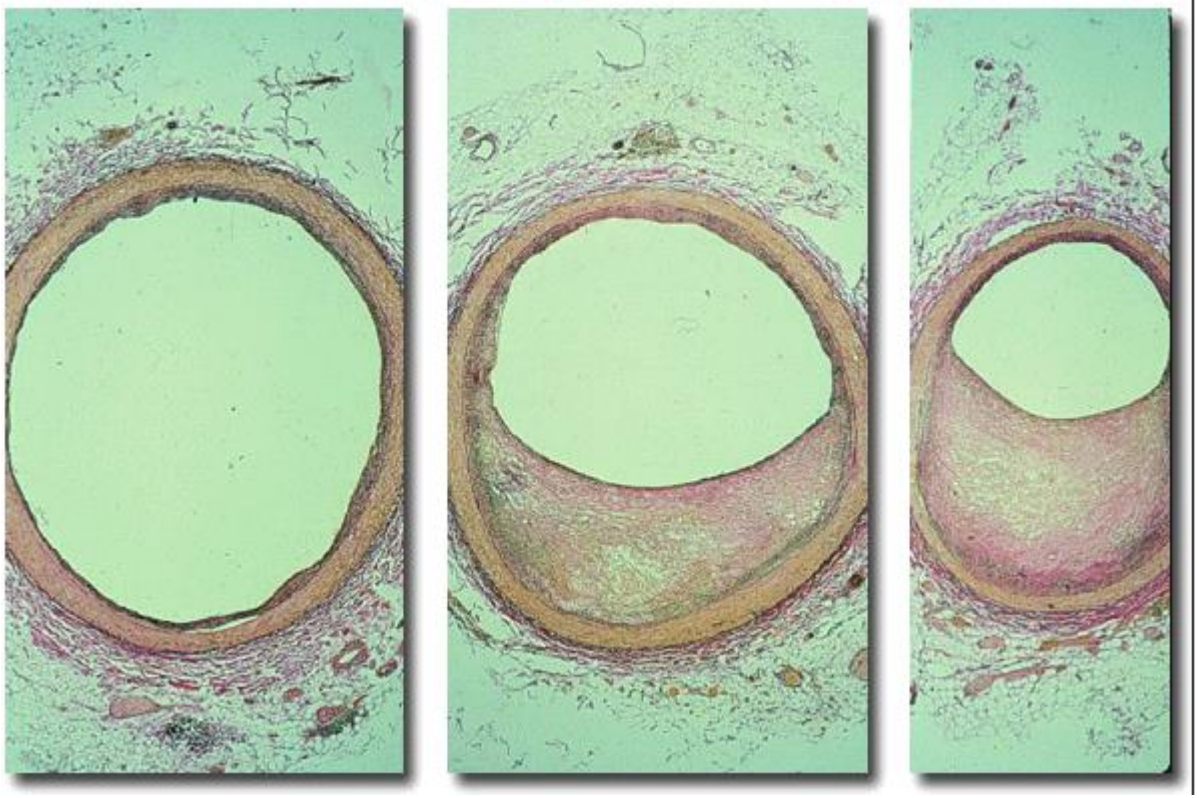


Arterial Anatomy (normal)





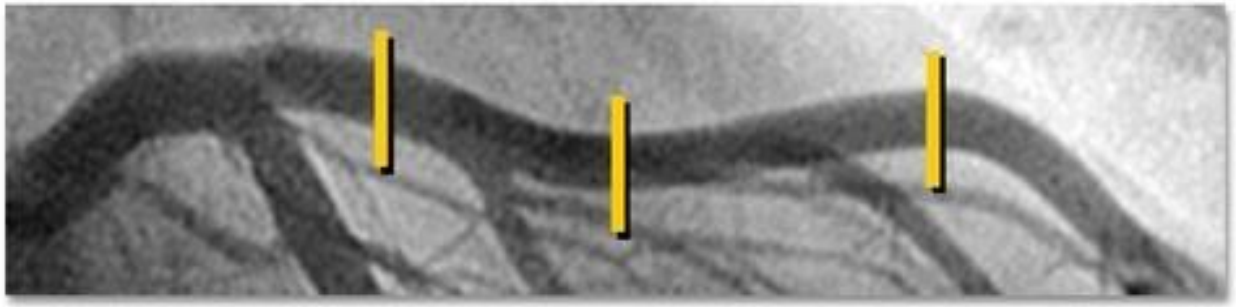
What is a stenosis ?

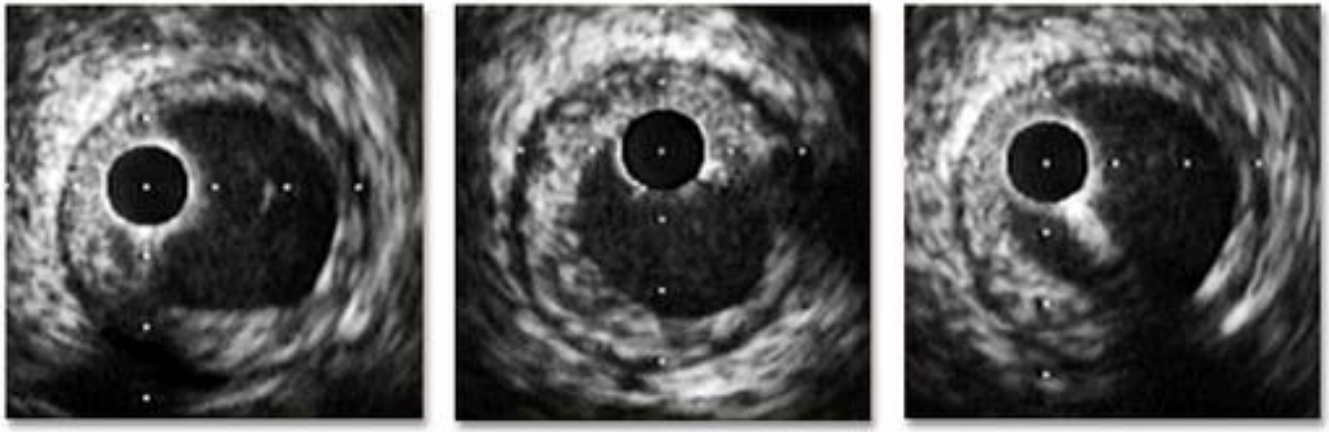


Stenosis

lumen narrowing caused by a disease in the wall

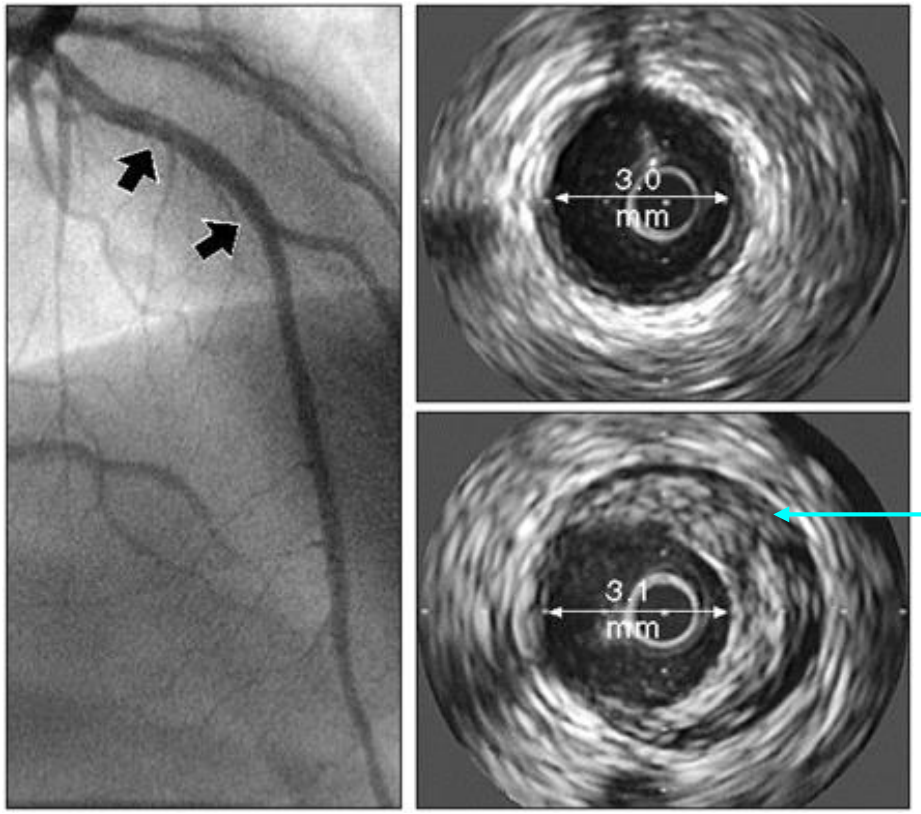
Intravascular ultrasounds (IVUS)





The IVUS technique can detect angiographically ‘silent’ atheroma

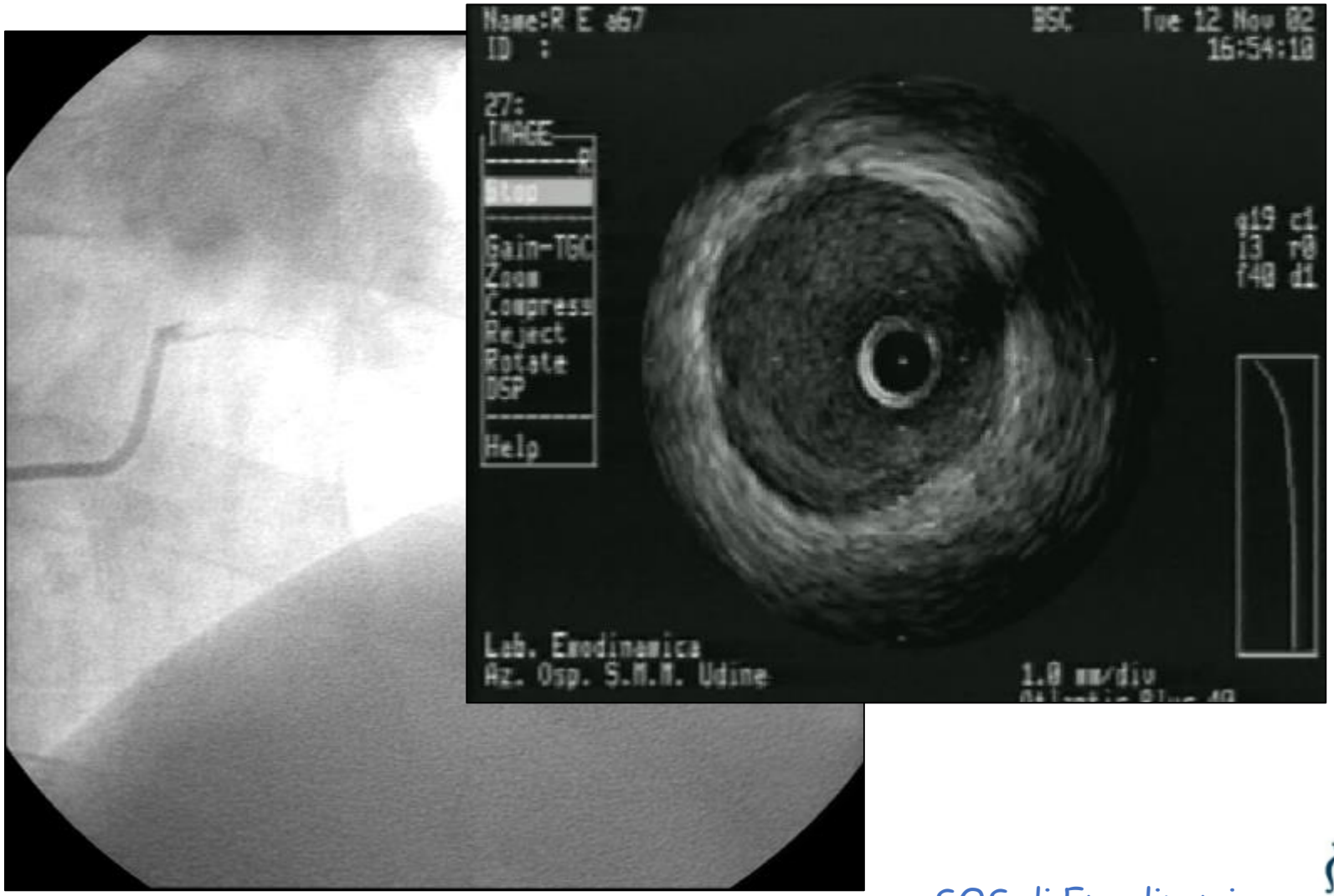
No evidence of disease



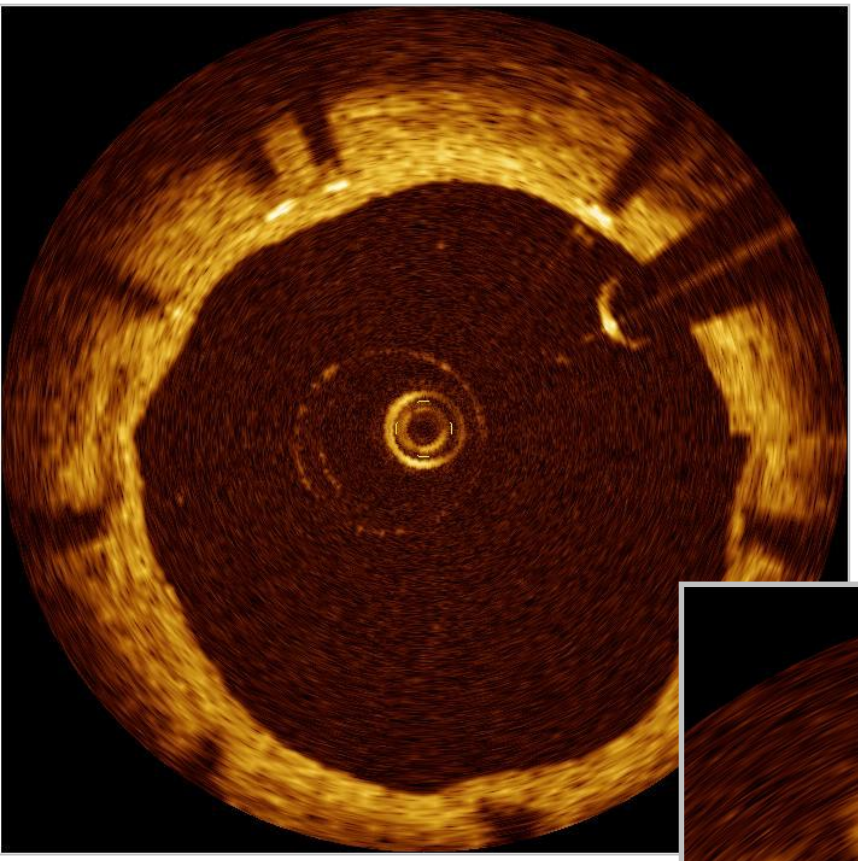
Little evidence of disease

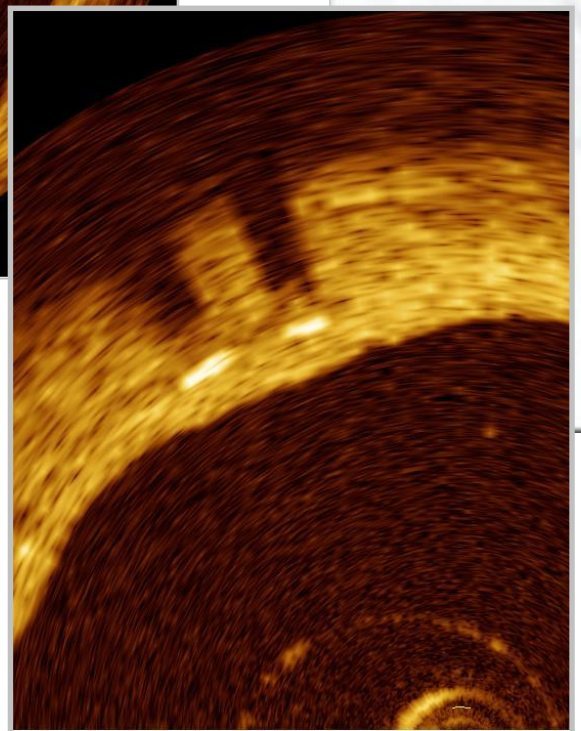
Atheroma

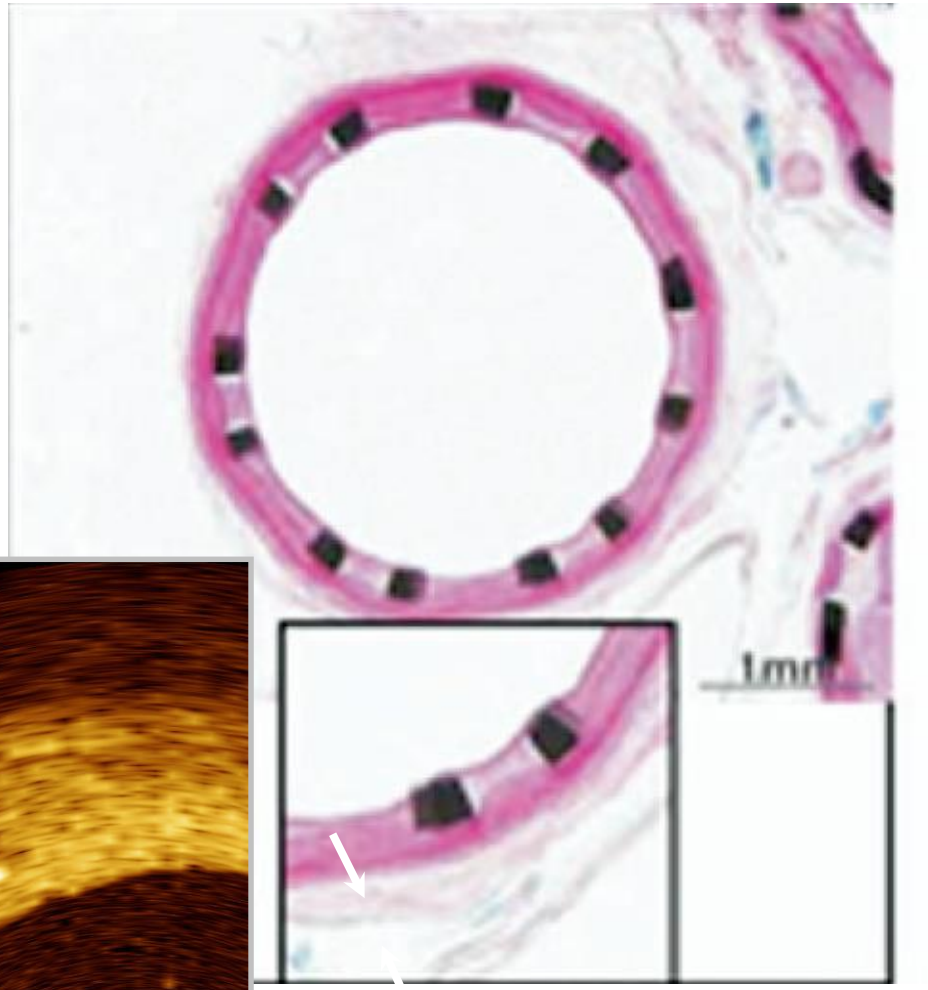
Non-critical but “complicated” stenosis



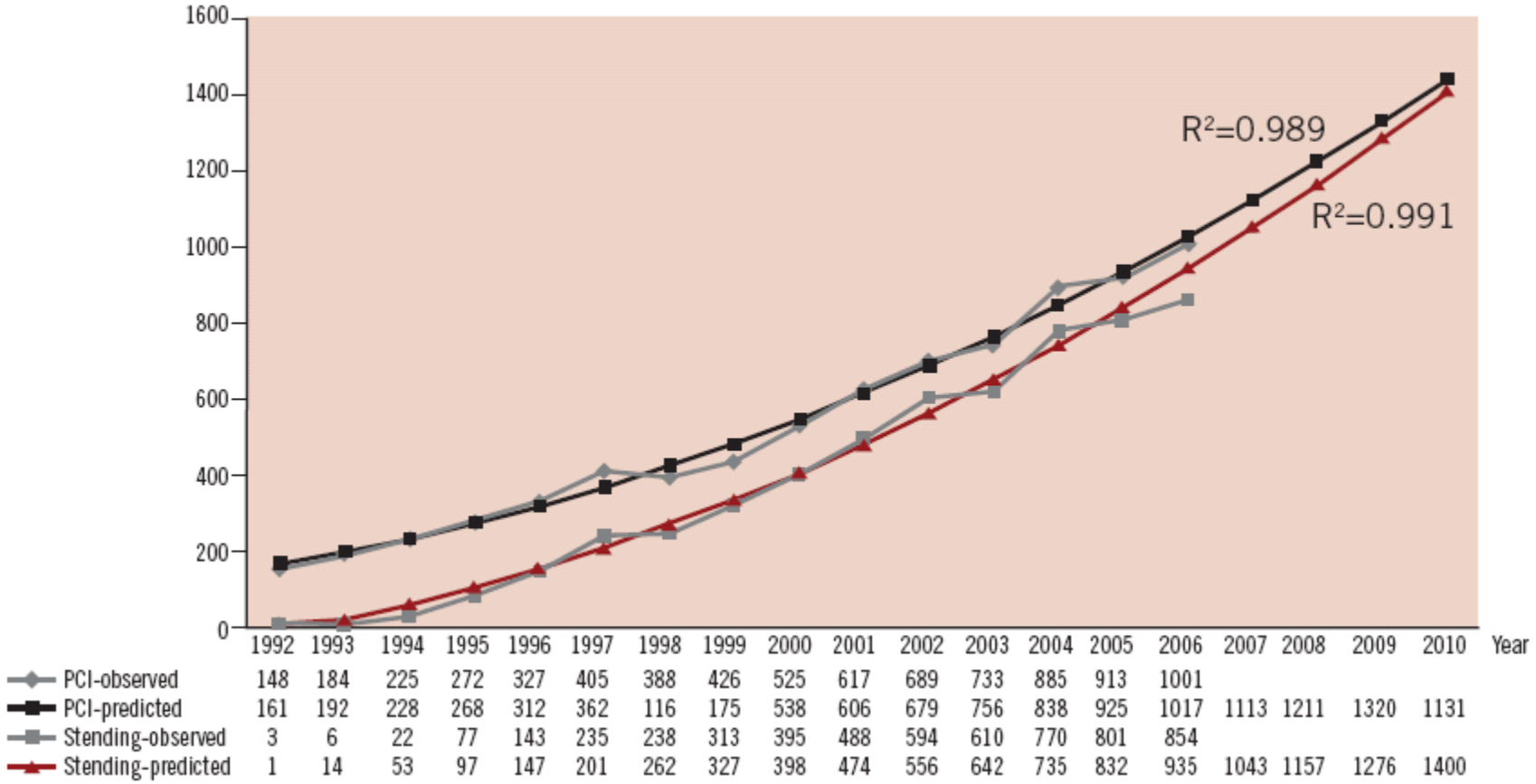
Optical Coherence Tomography (OCT)







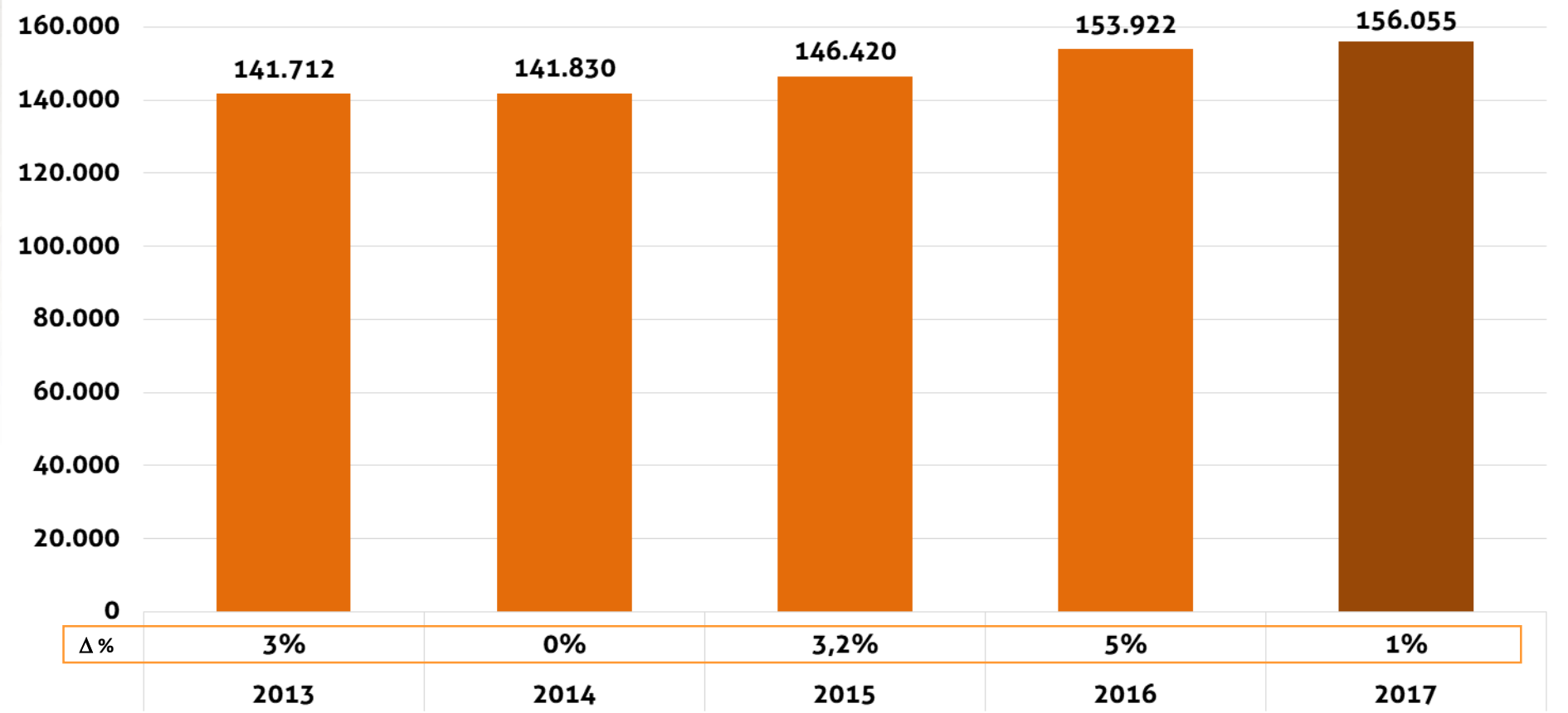
Percutaneous coronary interventions in Europe



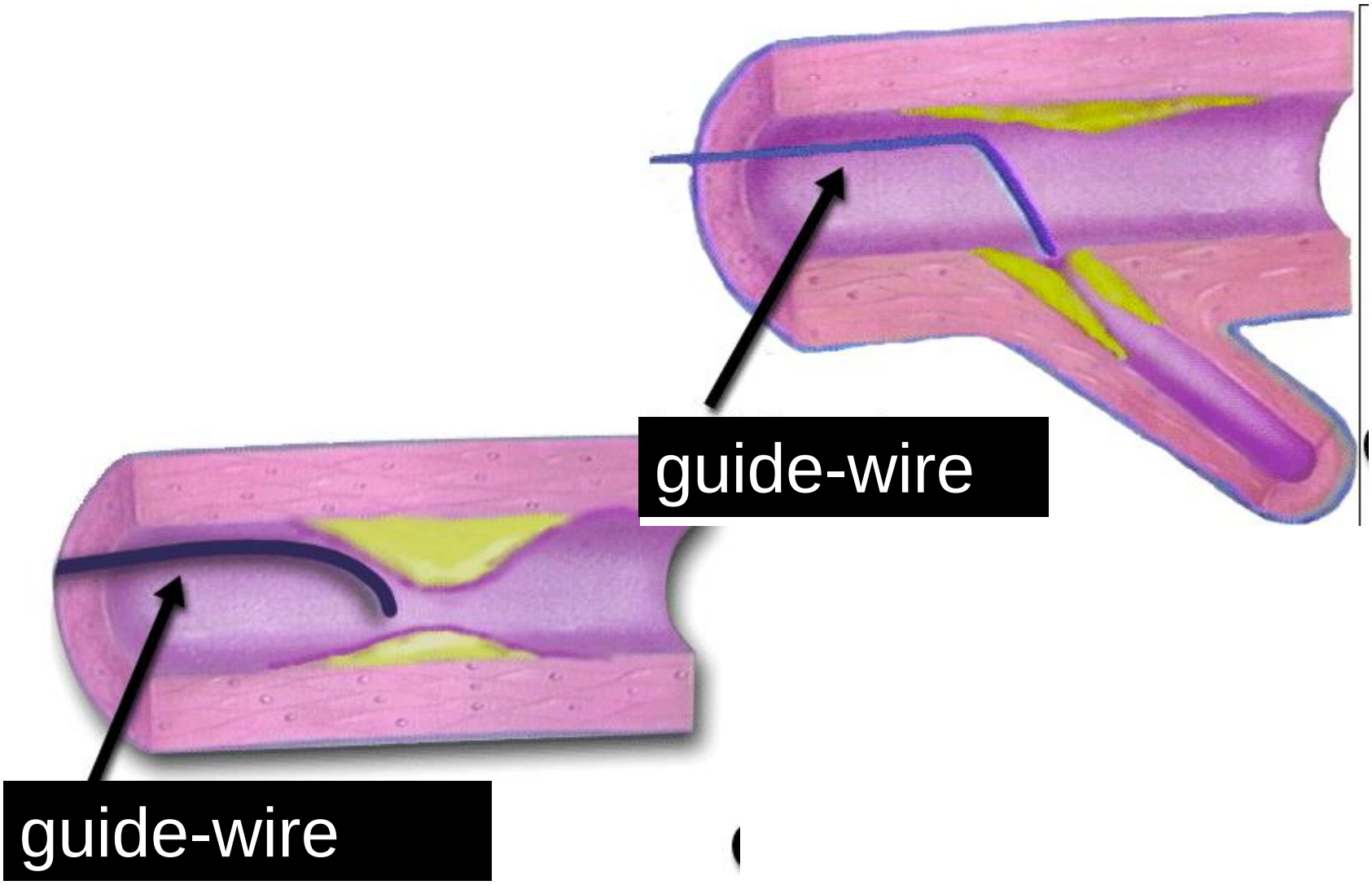
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Year
PCI-observed	148	184	225	272	327	405	388	426	525	617	689	733	885	913	1001					
PCI-predicted	161	192	228	268	312	362	116	175	538	606	679	756	838	925	1017	1113	1211	1320	1131	
Stending-observed	3	6	22	77	143	235	238	313	395	488	594	610	770	801	854					
Stending-predicted	1	14	53	97	147	201	262	327	398	474	556	642	735	832	935	1043	1157	1276	1400	

Moschovitis A, Eurointervention 2010;6:189

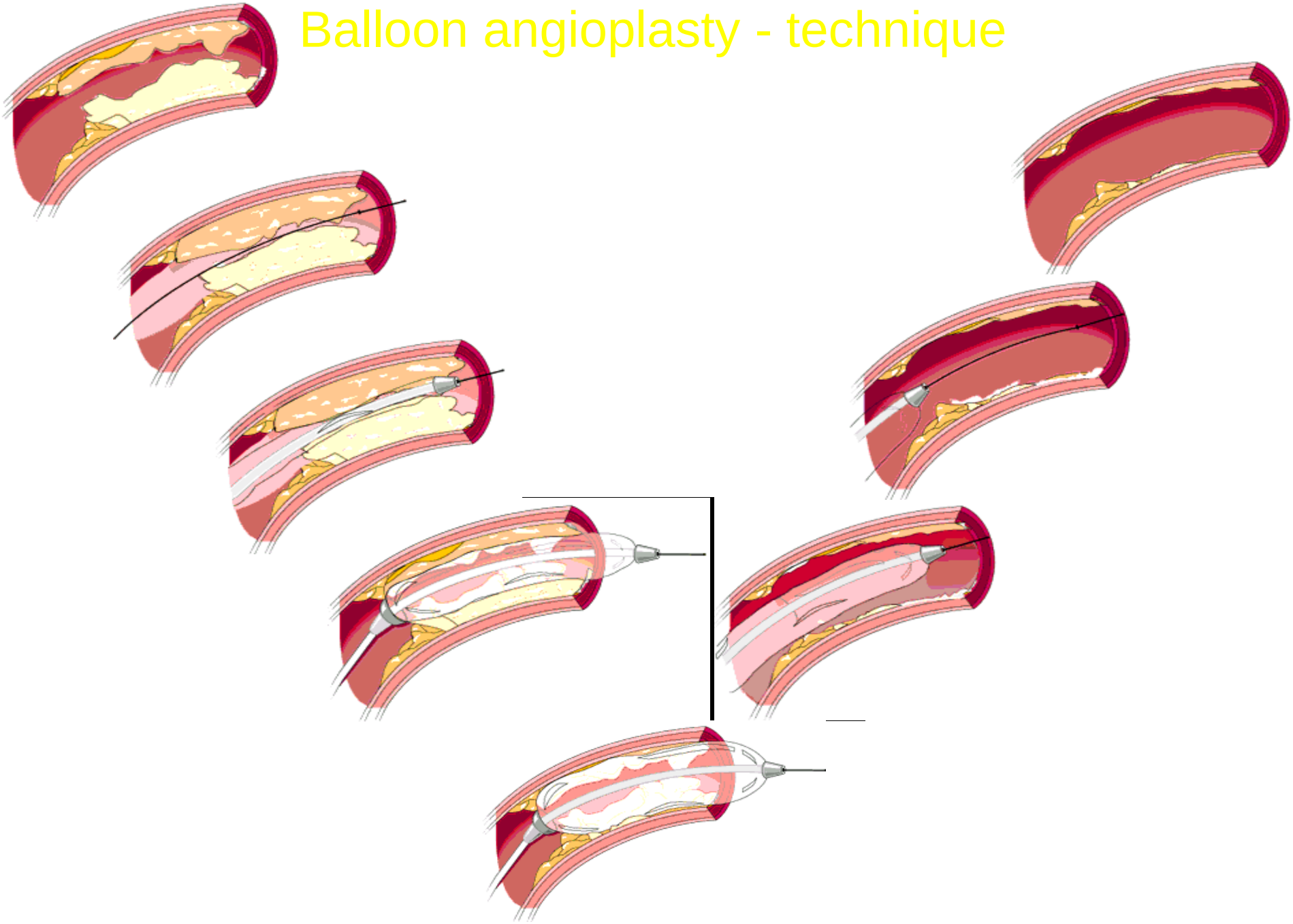
PCI
ITALIA SERIE STORICA



Coronary balloon angioplasty - technique

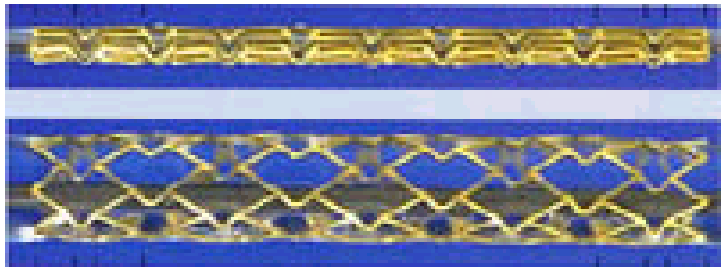


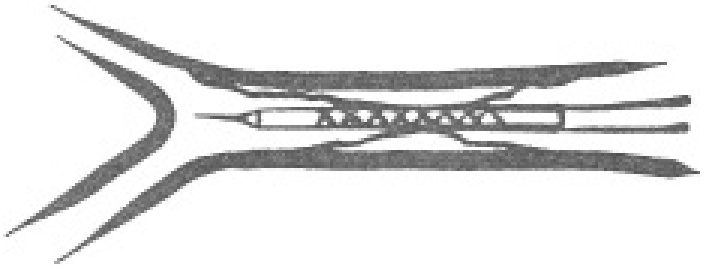
Balloon angioplasty - technique

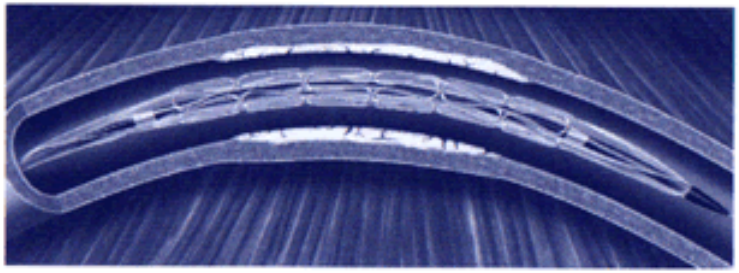


PTCA with stent

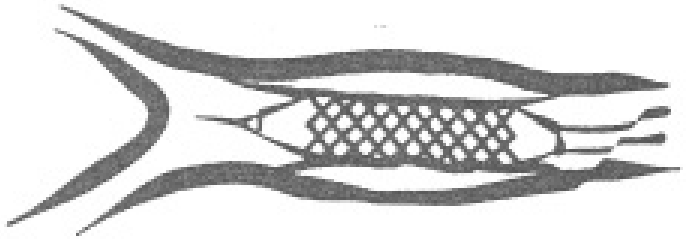
technique

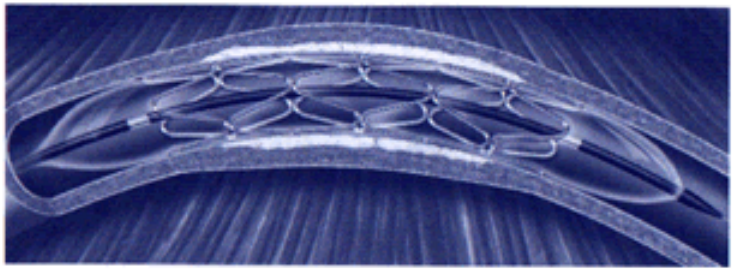




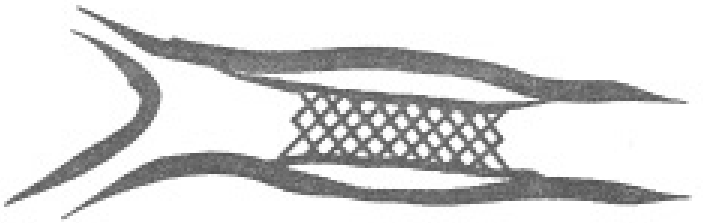


Stent Mounted on Balloon



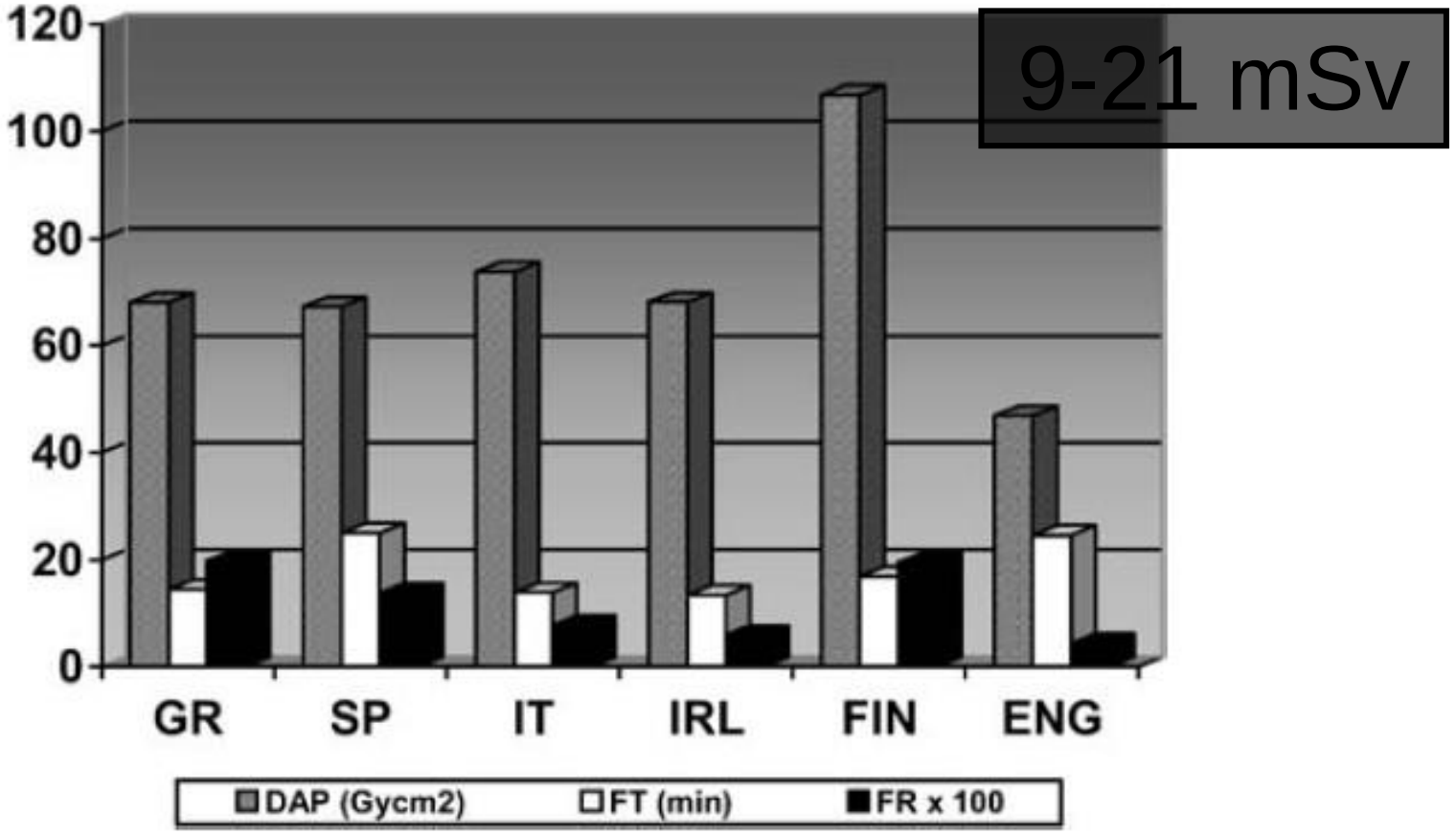


Stent with Balloon Inflated



Variability in exposure accross different cente in coronary angioplasty

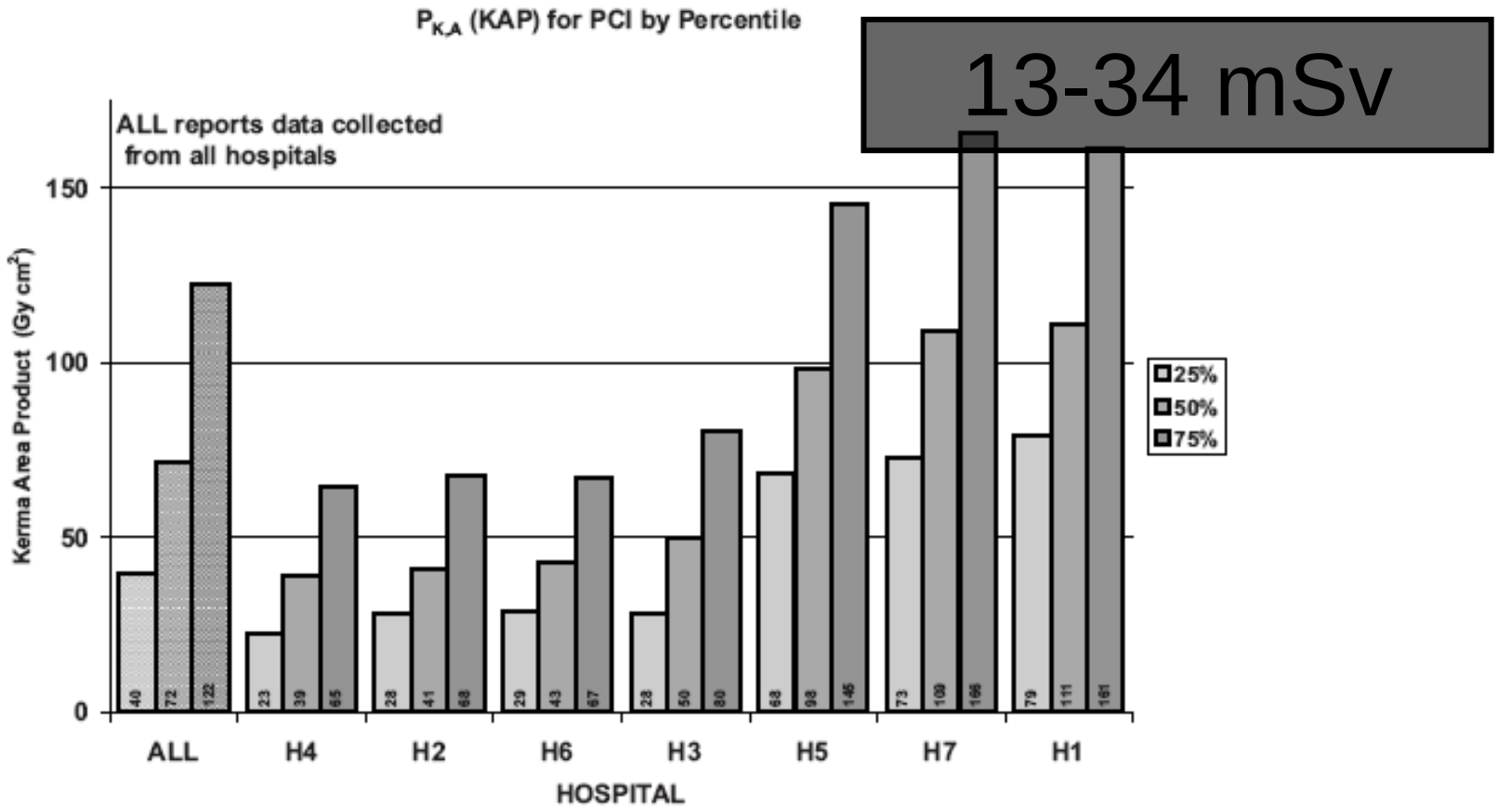
mean fluoroscopy time, frame number and dose-area product (DAP) in six European centers (600 procedures, third-quartile values)



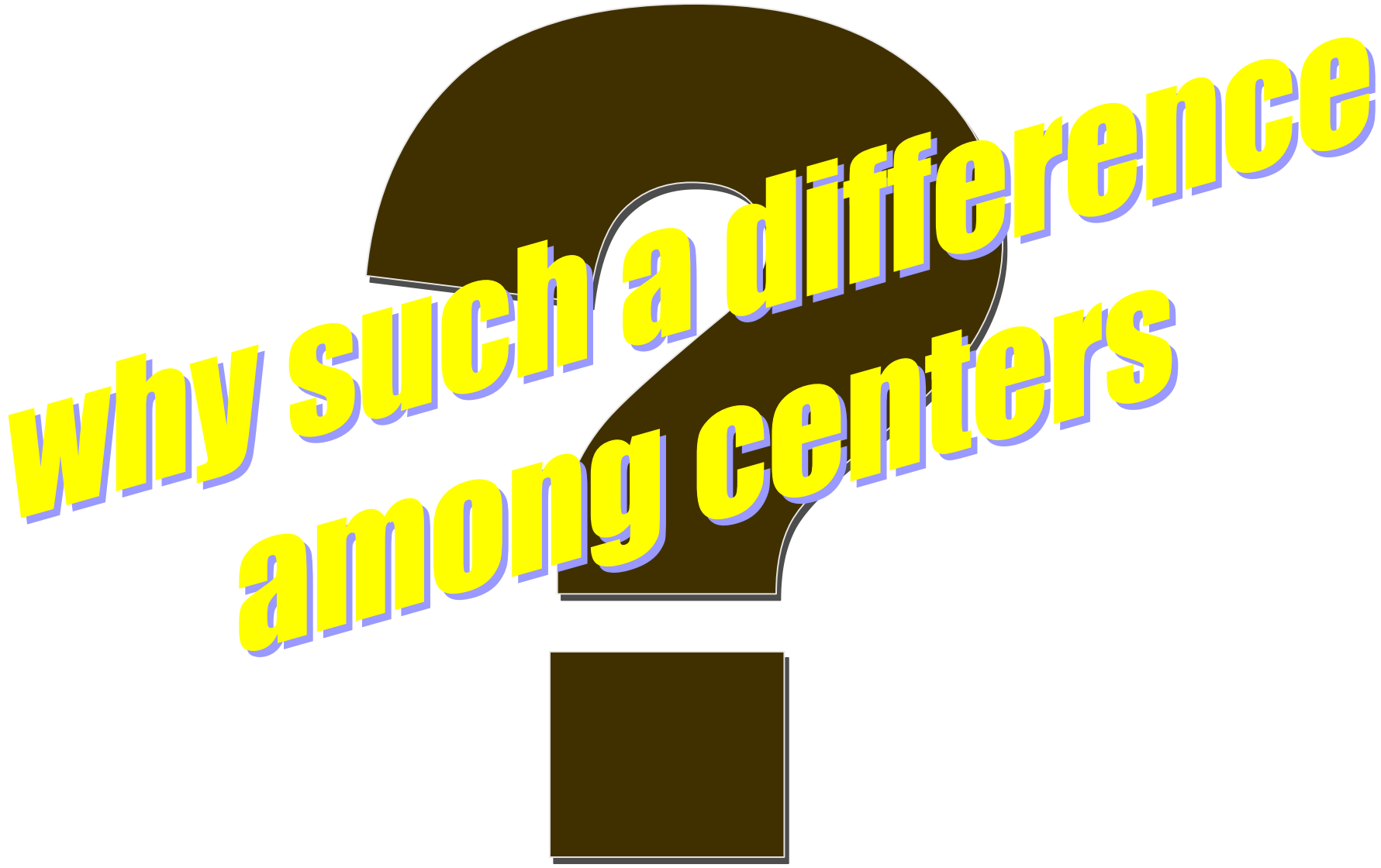
Neofotistou, European Radiology 2003

Variability in exposure accross different cent in coronary angioplasty

dose-area product (KAP) in seven centers (Chile, Italy, Spain, Uruguay, USA, 1844 procedures)

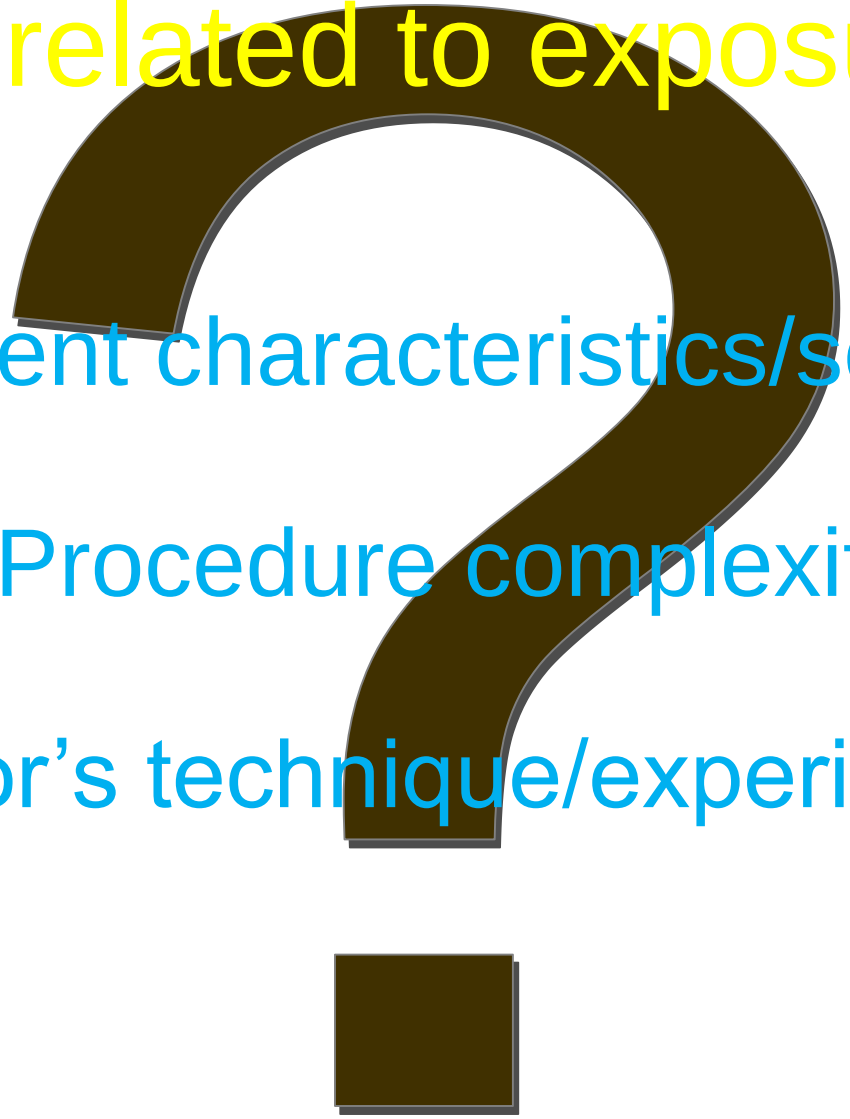


Balter, Medical Physics 2008


why such a difference among centers

Factors related to exposure

- Equipment characteristics/settings
- Patient/Procedure complexity
- Operator’s technique/experience



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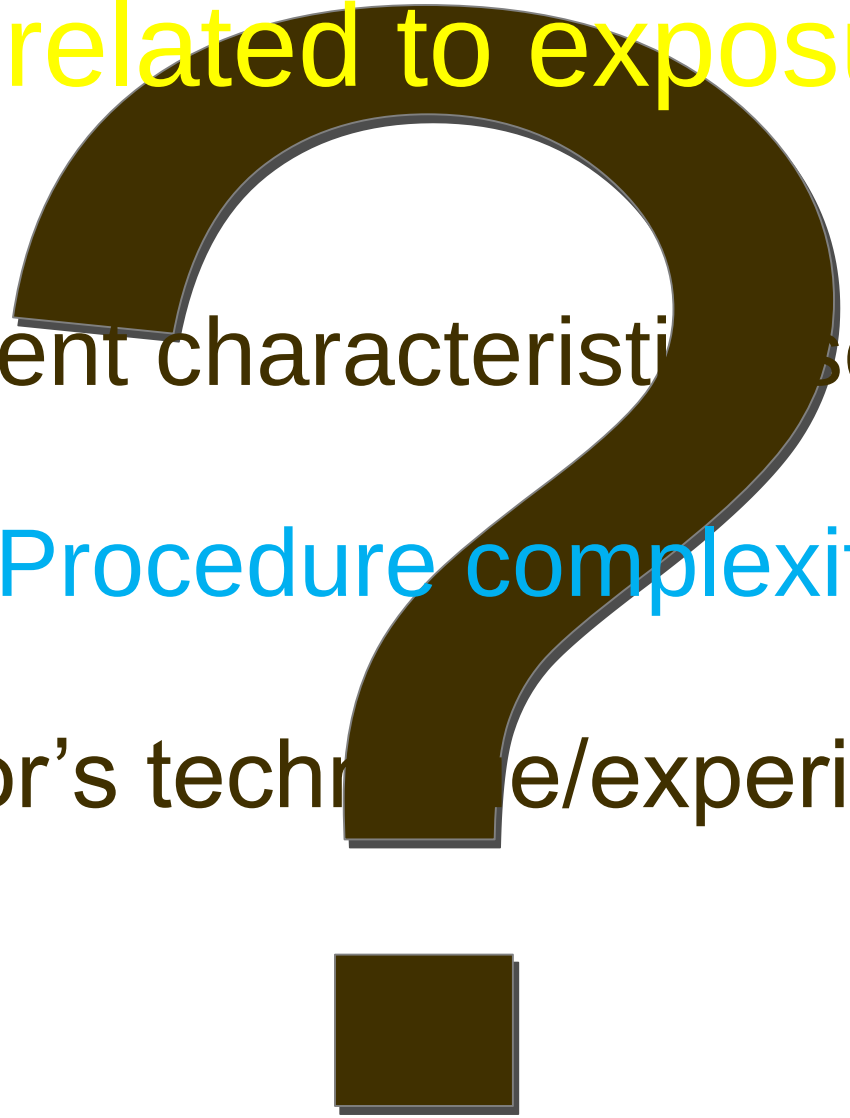
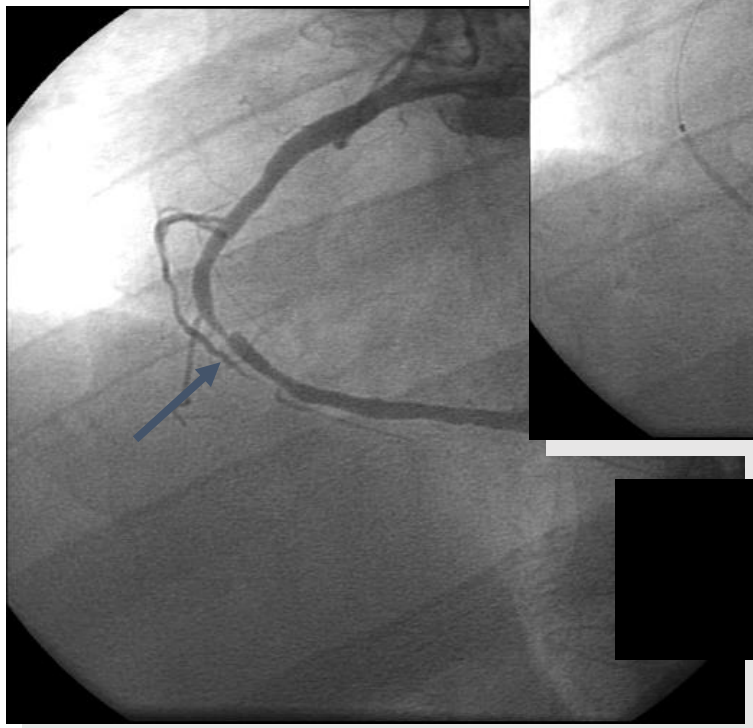
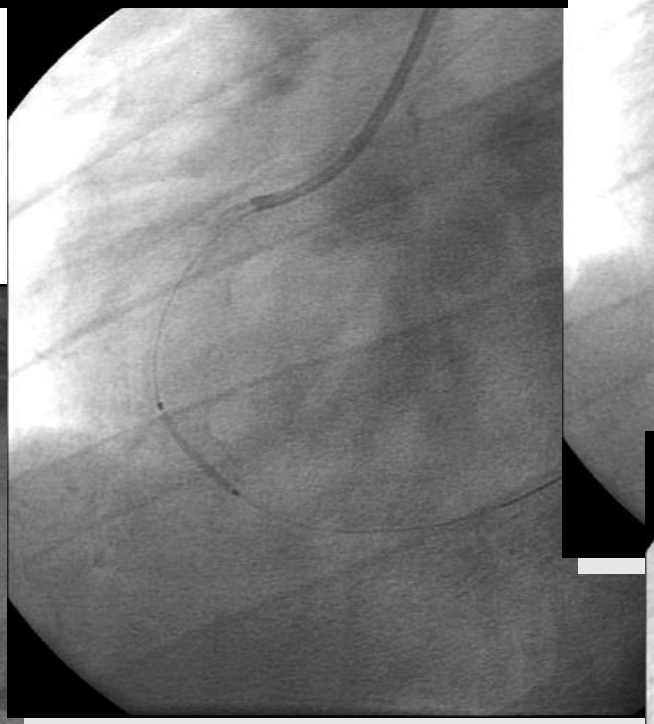
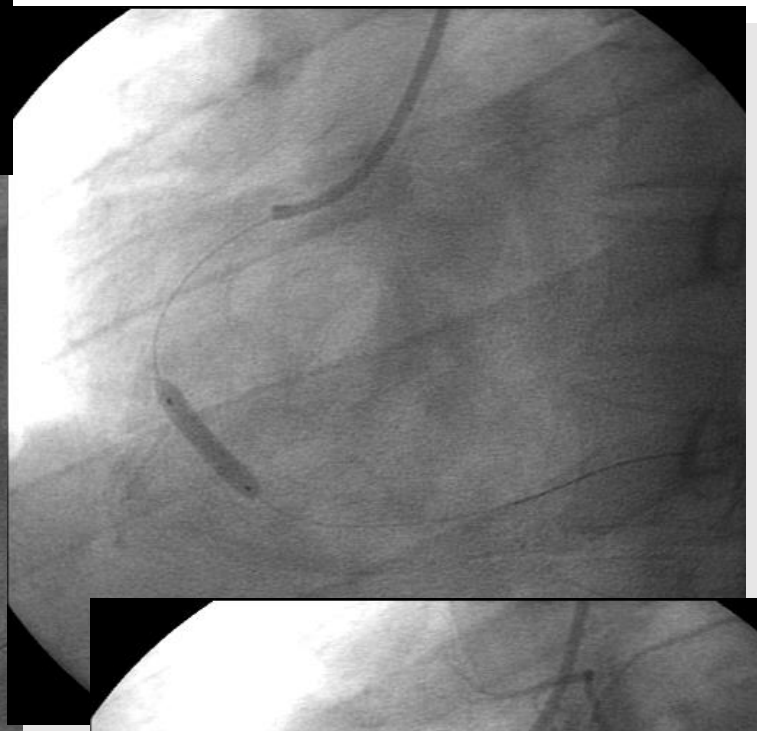
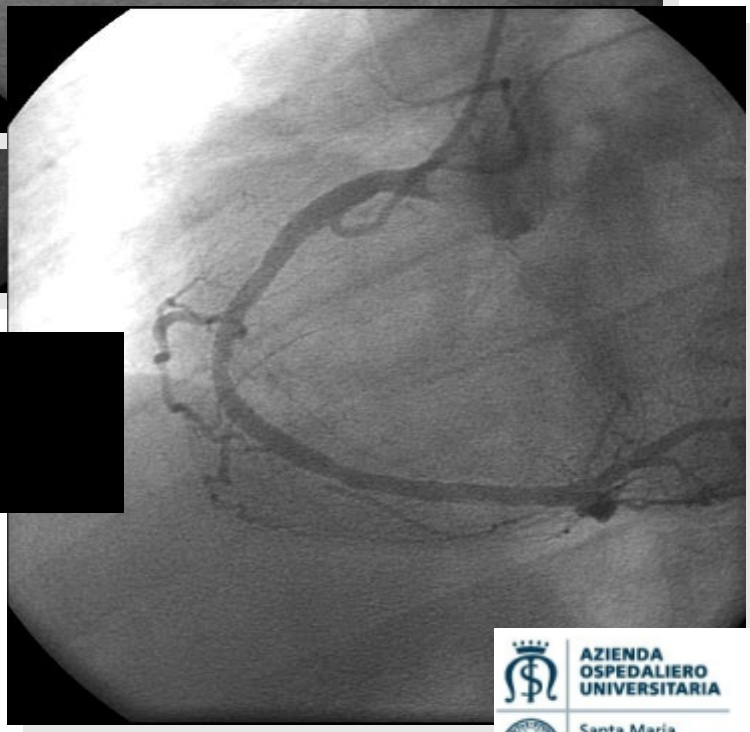


Case 1









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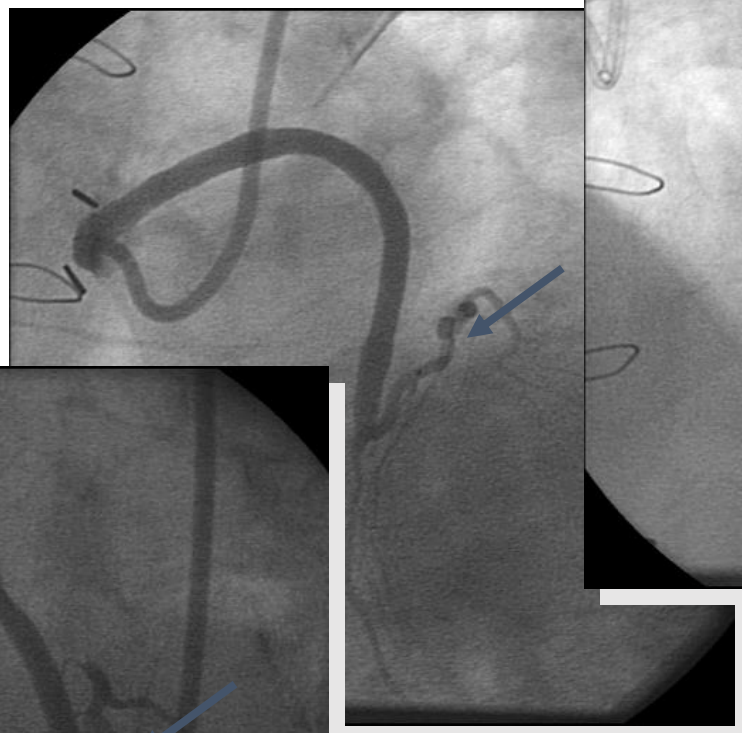
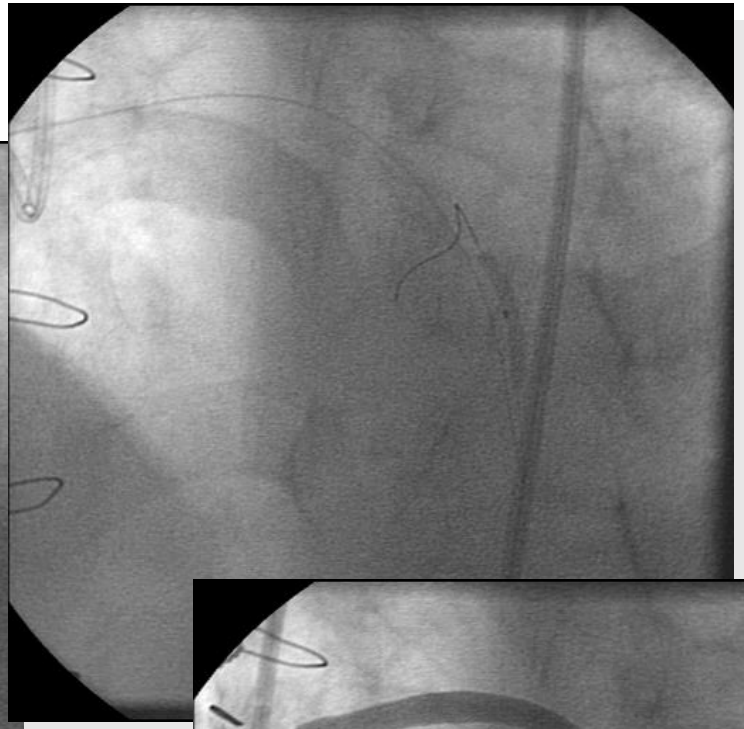
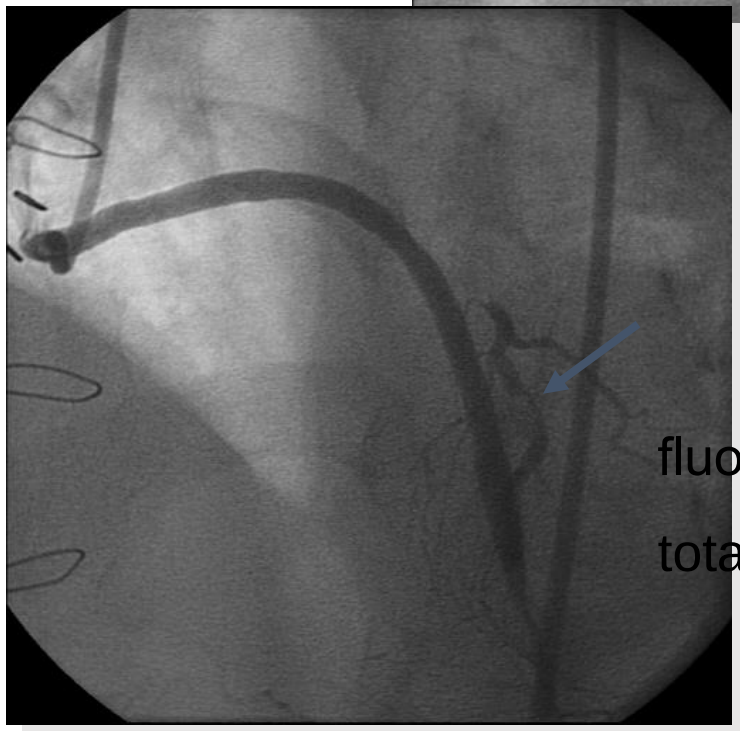
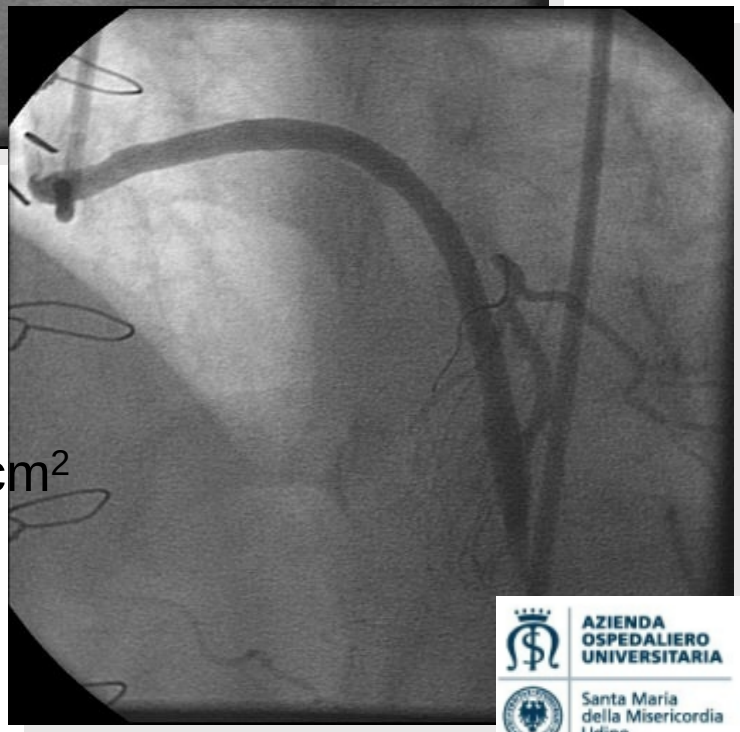
Case 2 *BSA 1,891 m^2*

Retrograde PCI on LAD via SVG









fluoro time: 20 m’

total DAP: 107,4 Gy/cm^2

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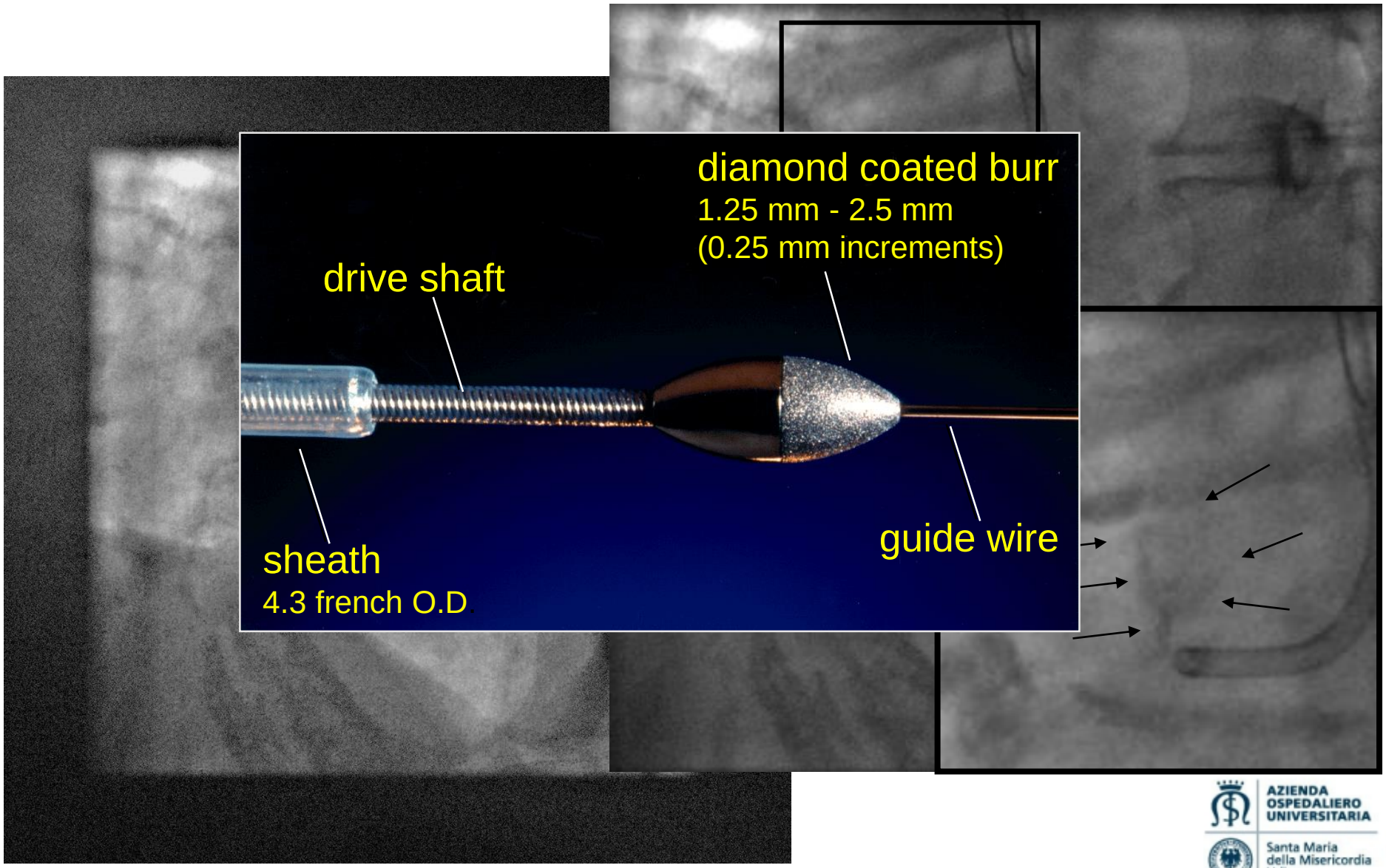
Santa Maria della Misericordia Udine

Case 3 *PCI of a calcified lesion with rotational atherectomy (Rotablator)*



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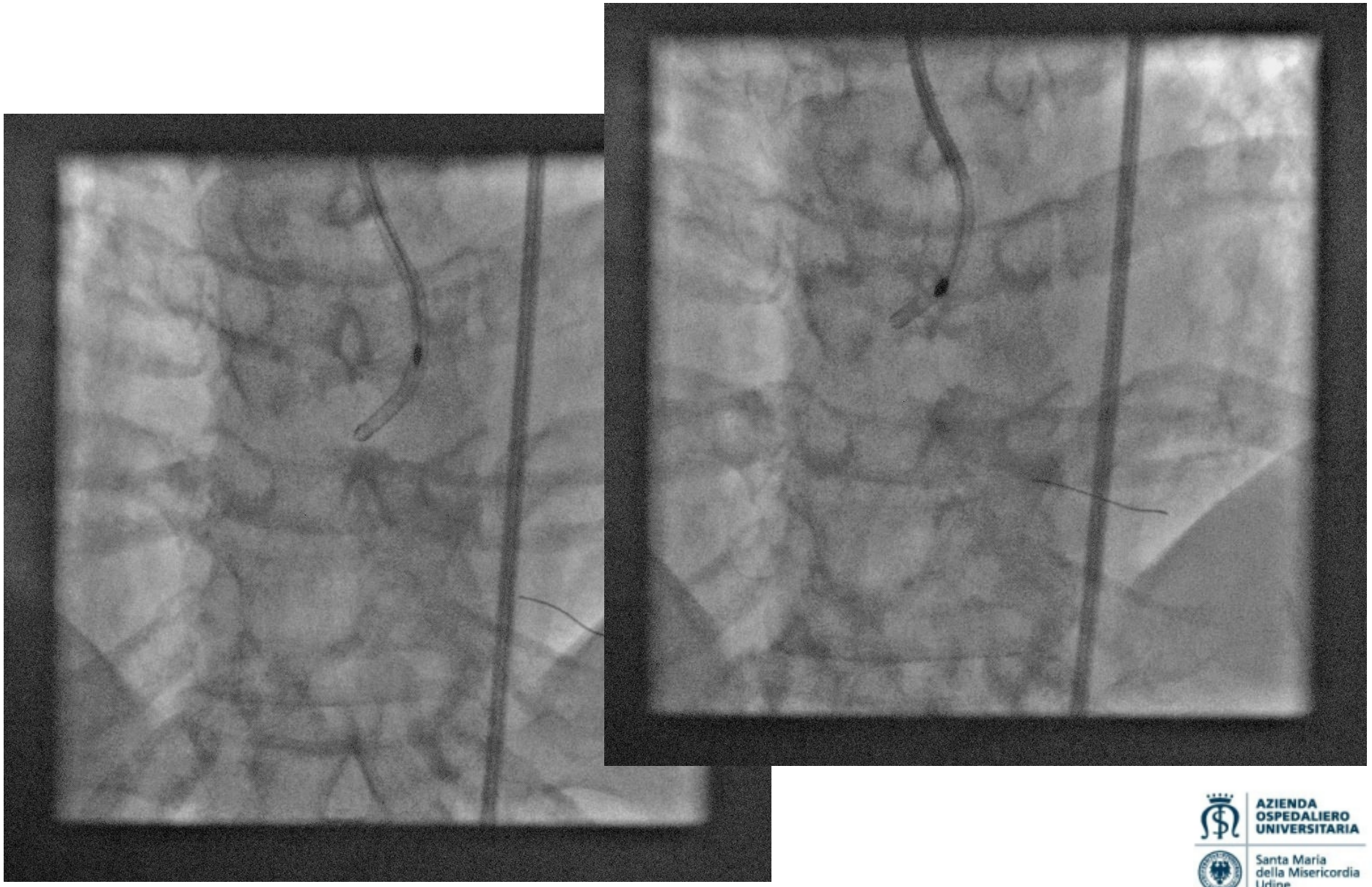
Santa Maria della Misericordia Udine

Case 3 *PCI of a calcified lesion with Rotablator*



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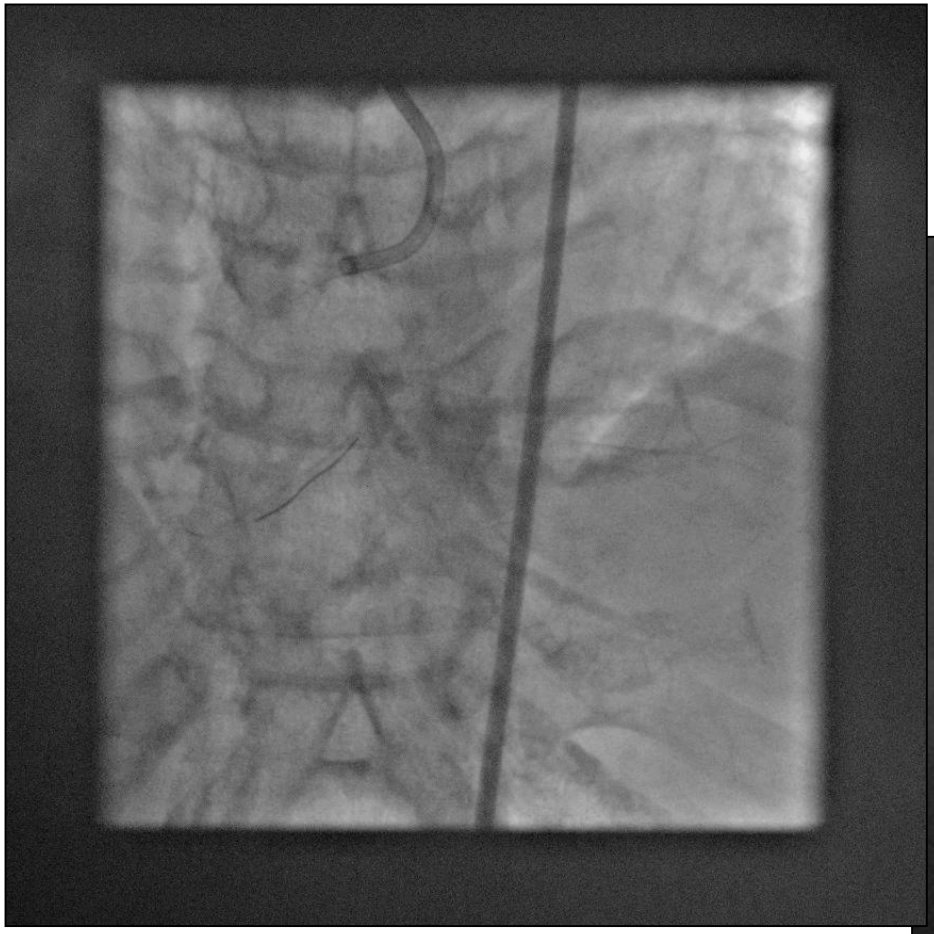
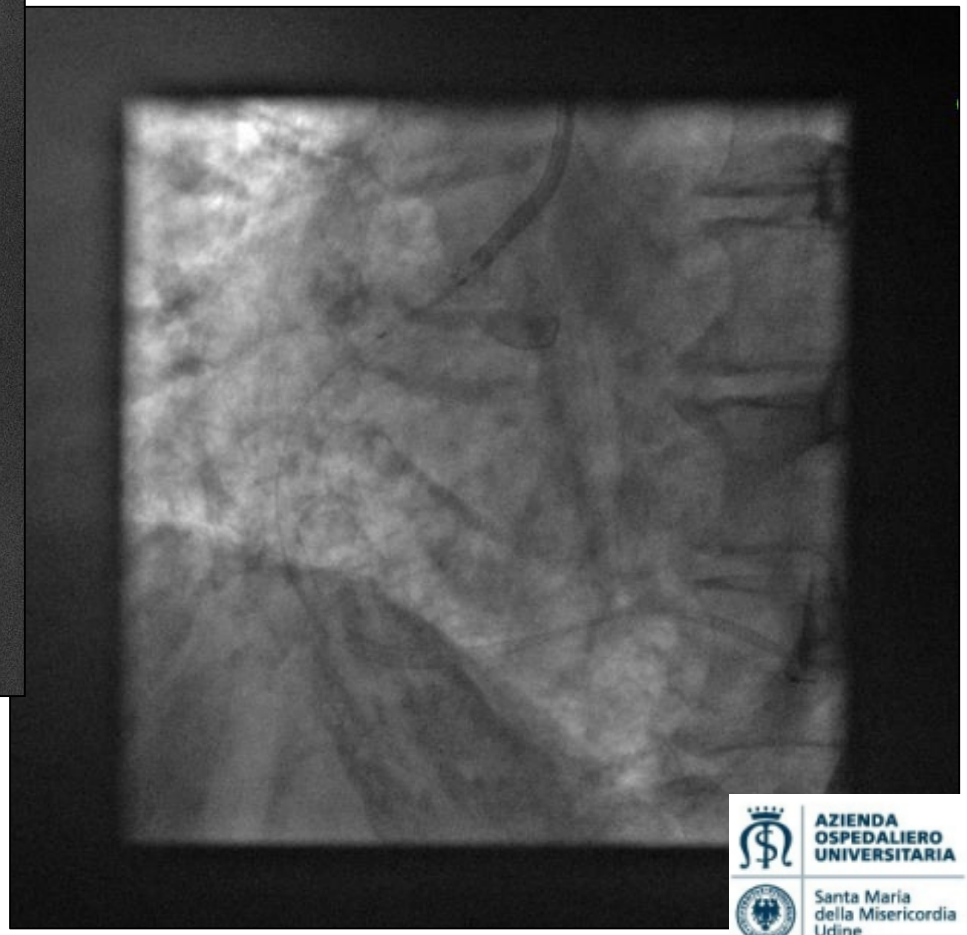
Case 3 *PCI of a calcified lesion with Rotablator*





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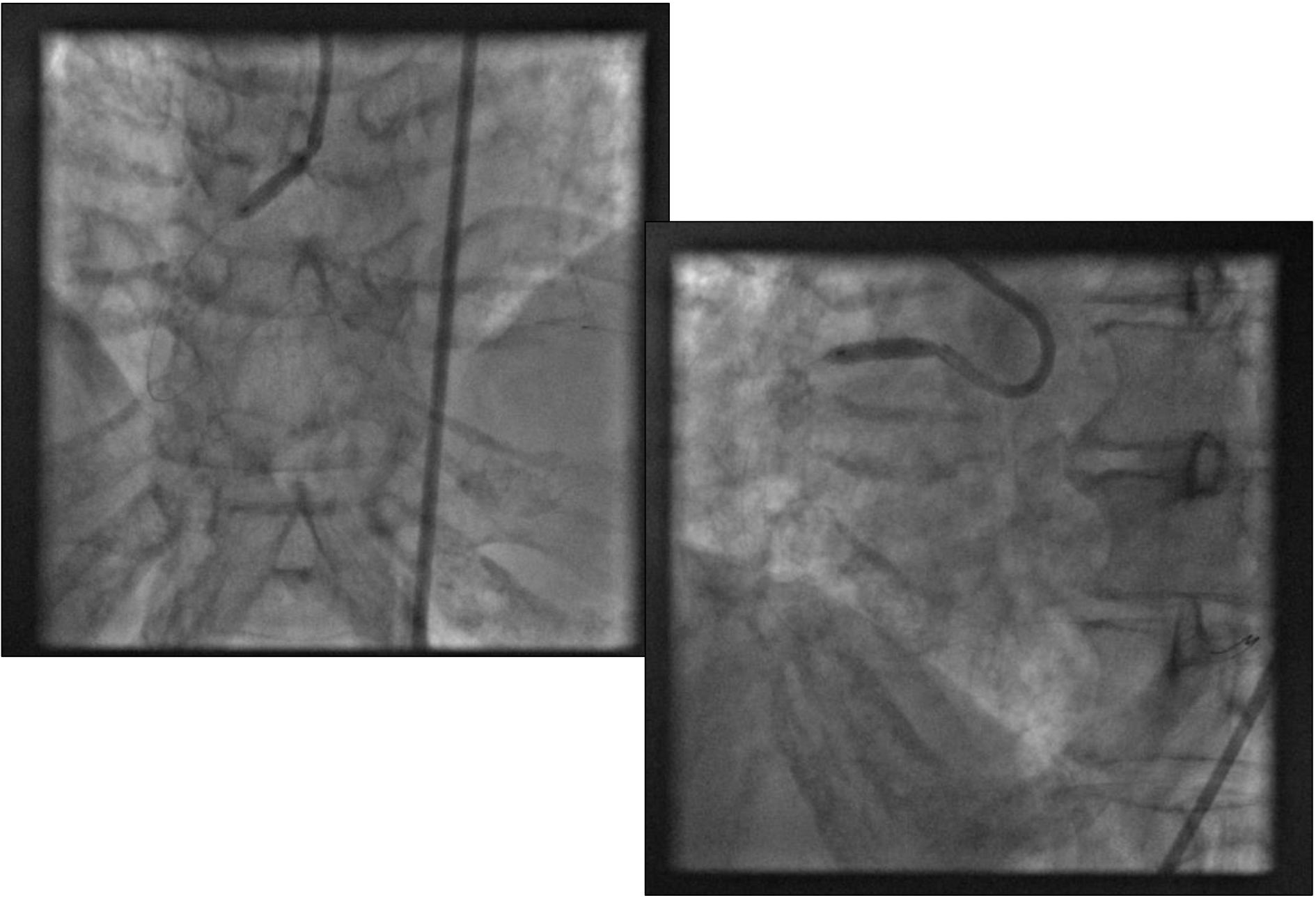
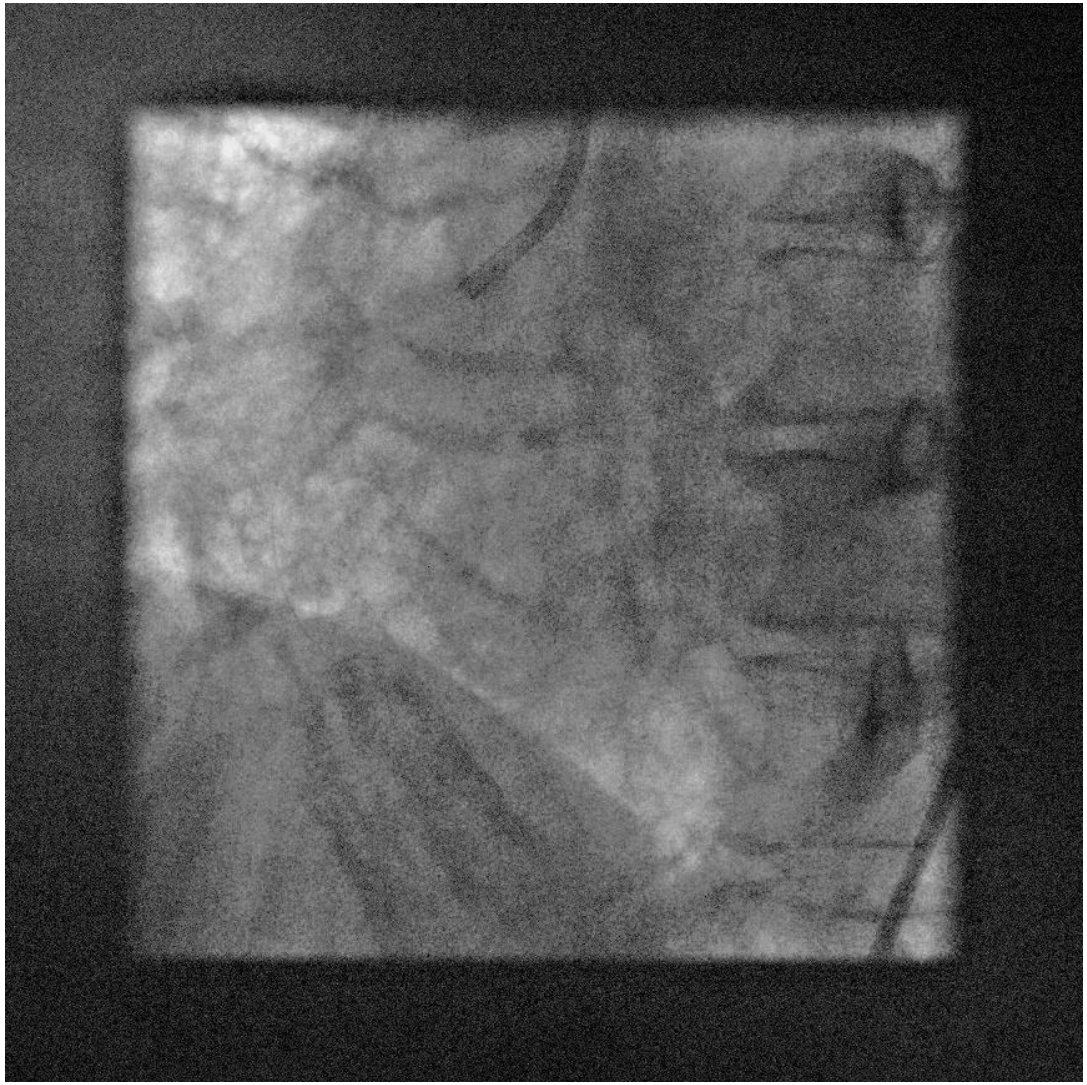
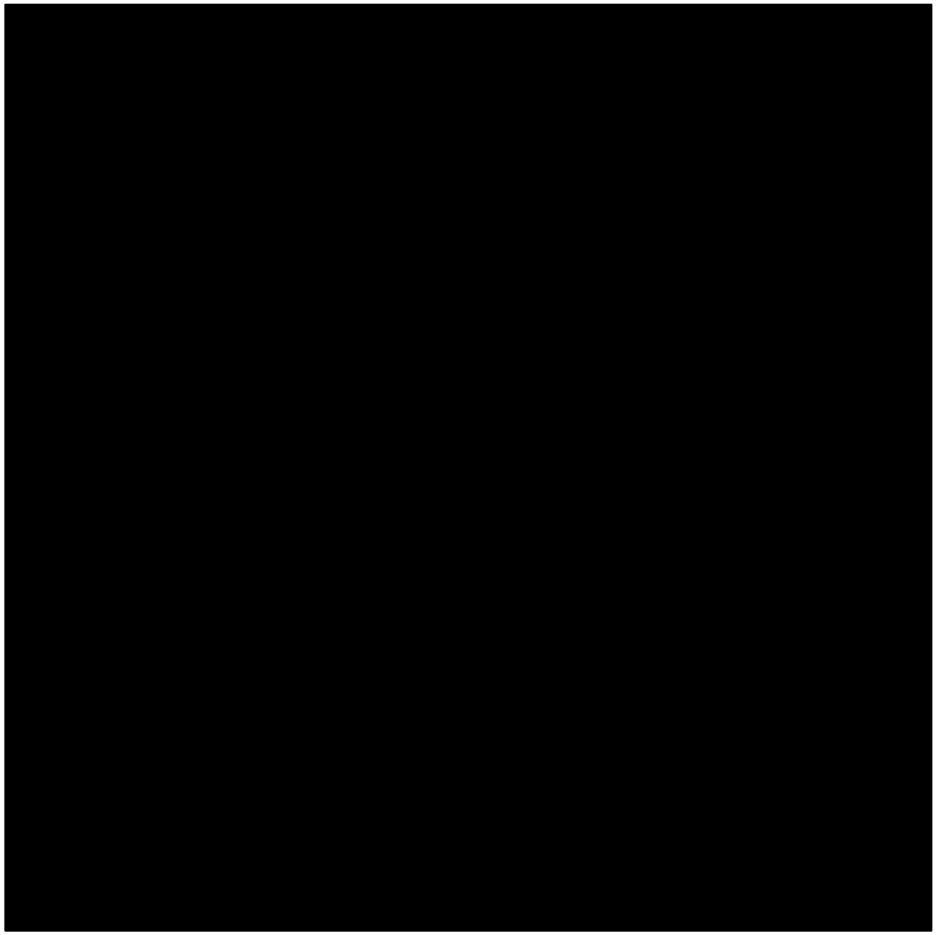


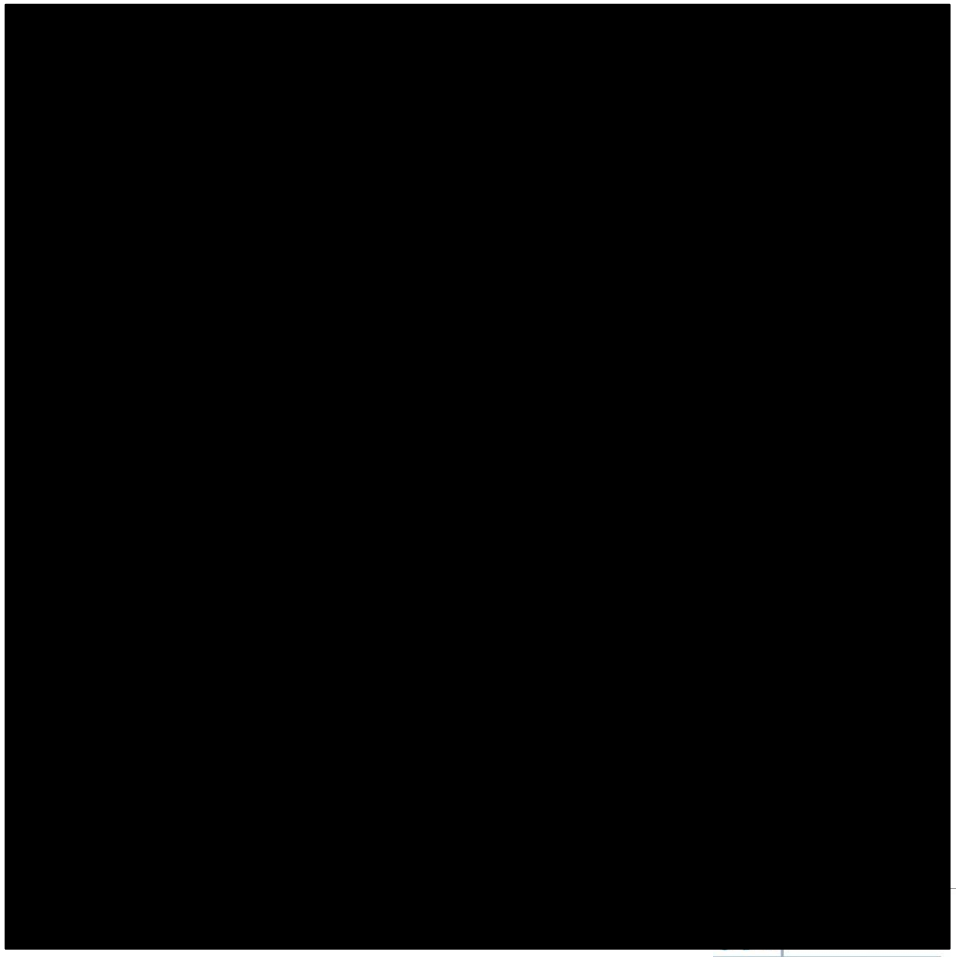
Case 3 *PCI of a calcified lesion with Rotablator*

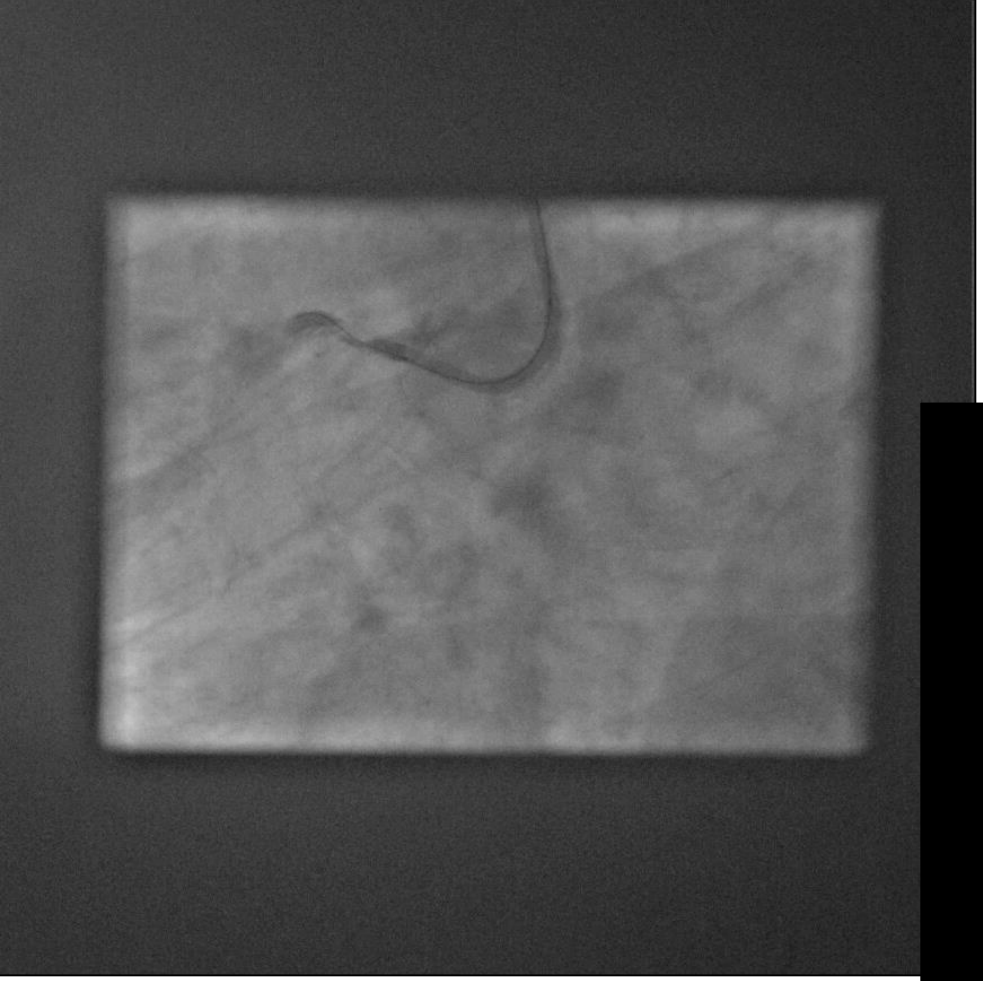
Final result

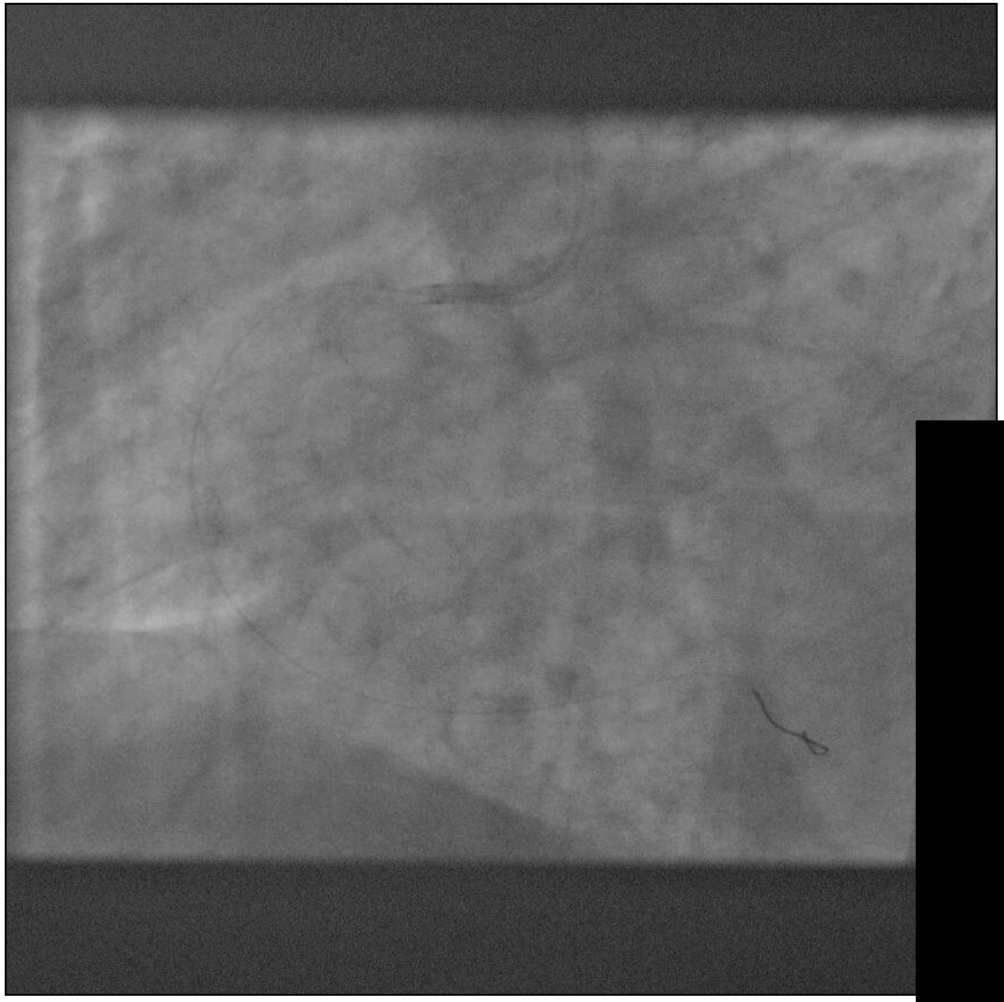


Case 4 *Right Coronary Artery Chronic Total Occlusion*









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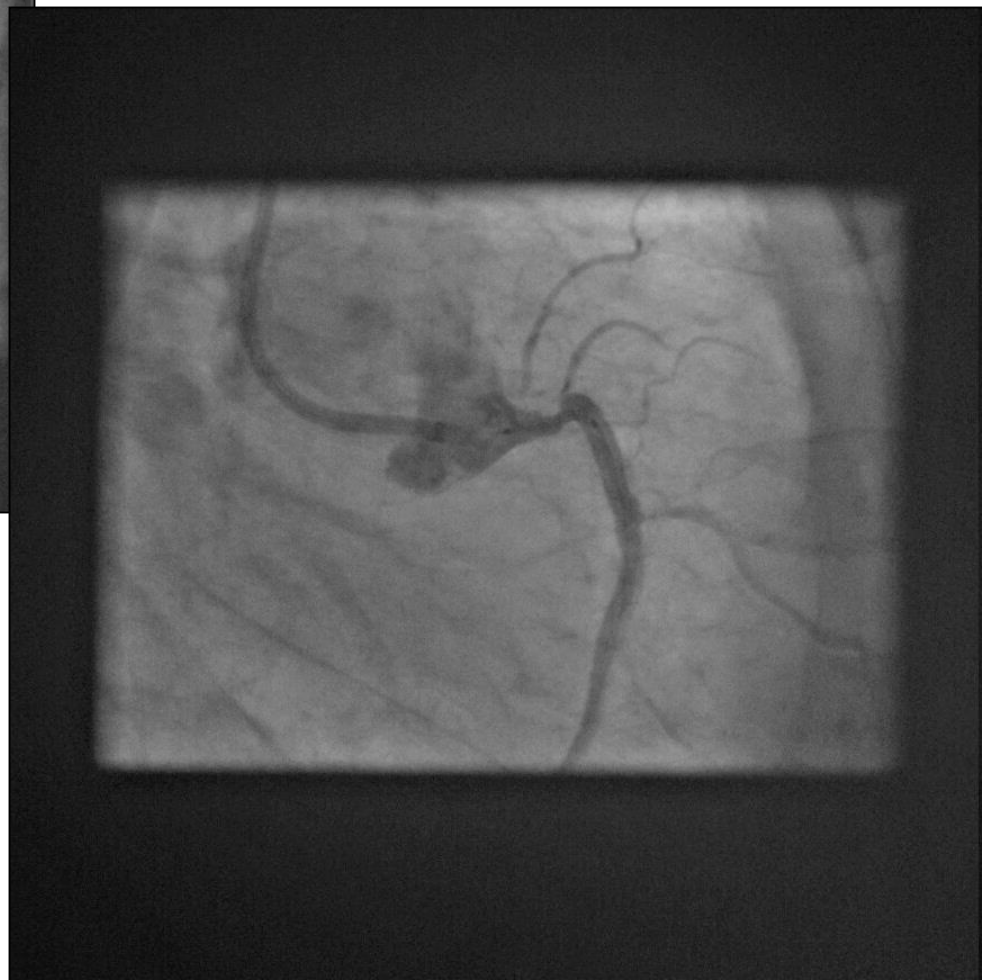
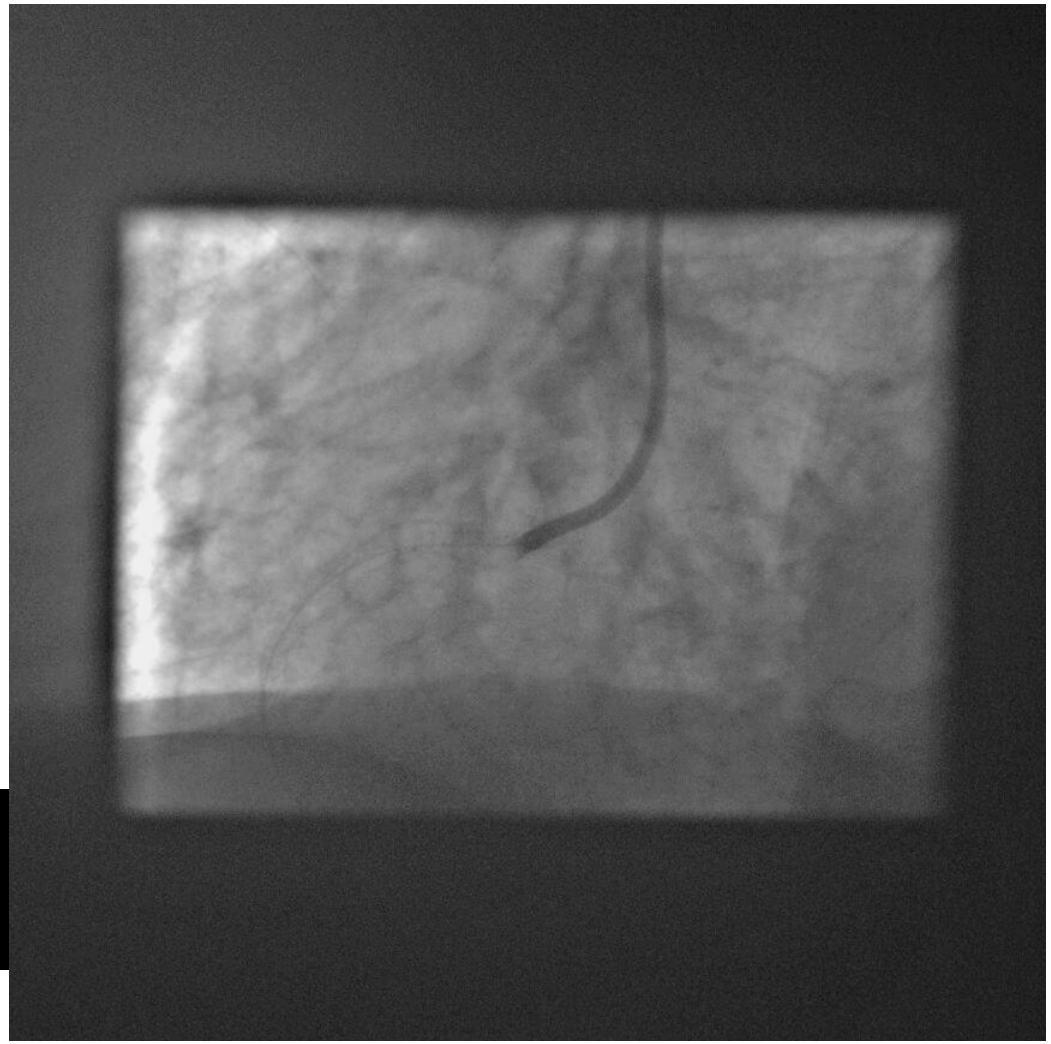


After TNT

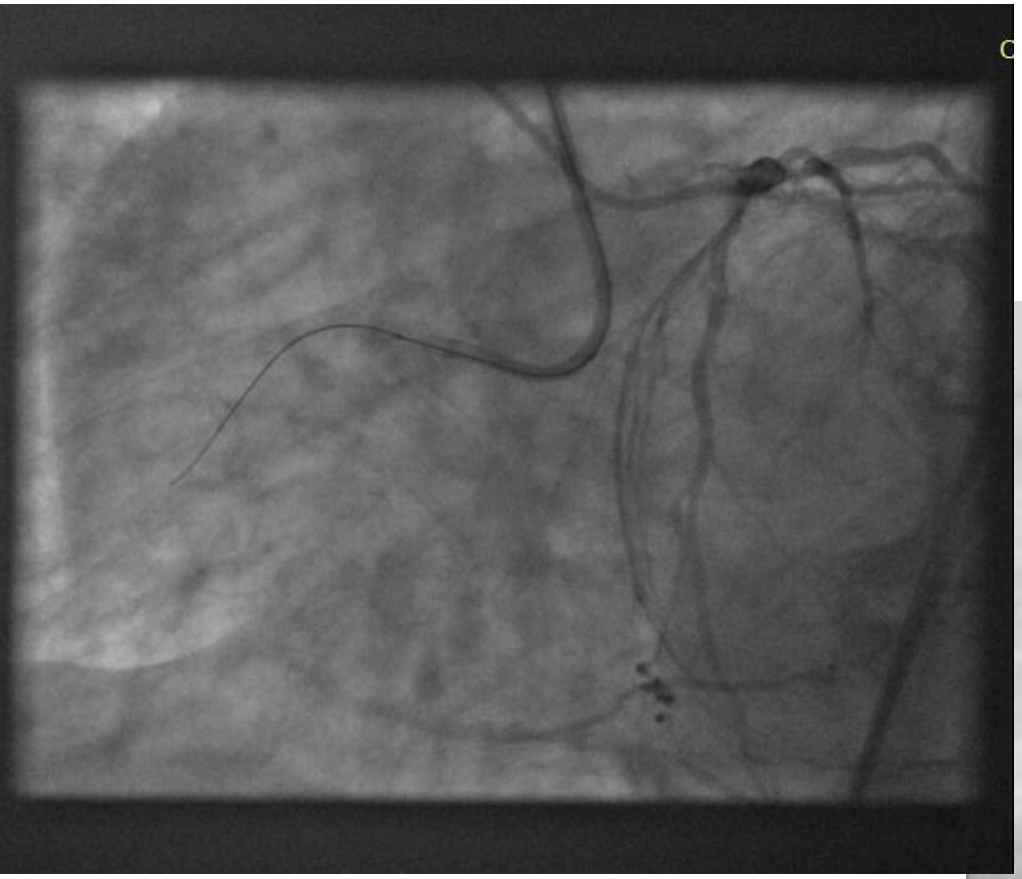
Case 4 *Right Coronary Artery Chronic Total Occlusion*

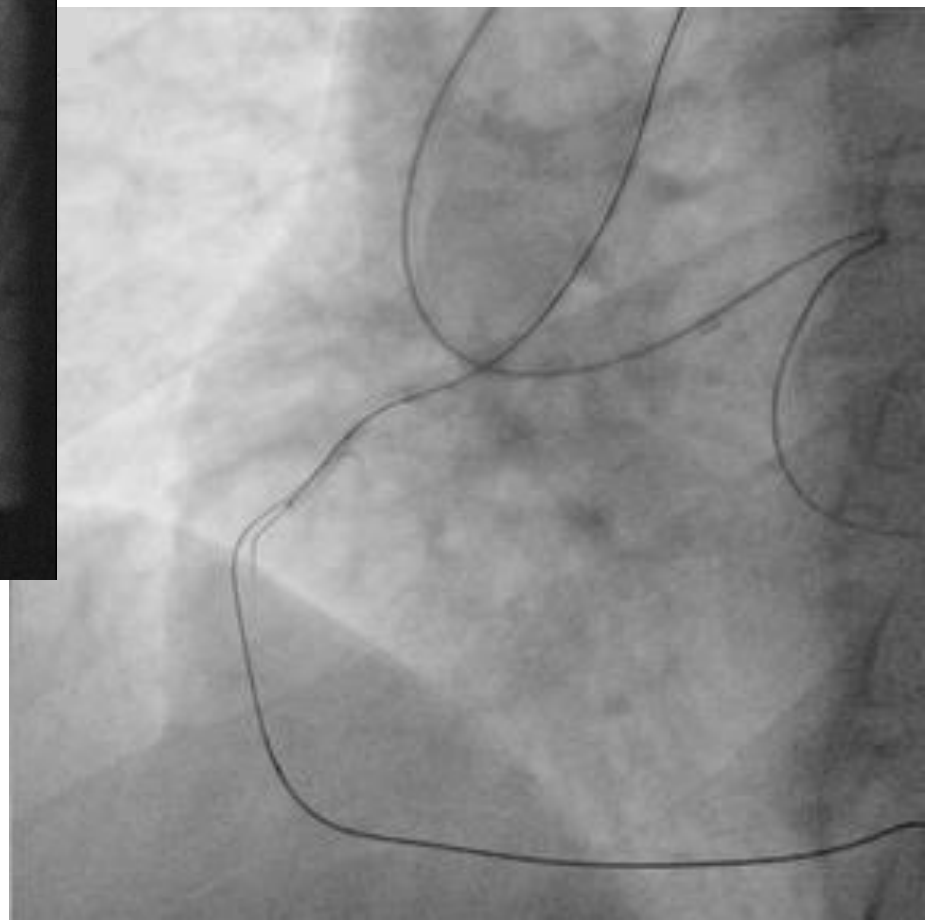
Final result



[redacted]

Retrograde approach to CTO





Patients' Skin Dose During PCI for Chronic Total Occlusion

Suzuki, CCI 2008

Catheterization and Cardiovascular Interventions 51:1–9 (2000)

Original Studies

Clinical and Technical Determinants of the Complexity of Percutaneous Transluminal Coronary Angioplasty Procedures: Analysis in Relation to Radiation Exposure Parameters

Guglielmo Bernardi,[1*] MD, Renato Padova
Maria Rosa Malisan,[2] PhD, Massim
and Paol

Independent variable	Regression coefficient (sec)	Score
No. of simple lesions	151*	1
No. of complex lesions	400*	2.6
IVUS (yes = 1; no = 0)	315*	2.1
No. of simple stenting	157*	1
No. of bifurcation stenting	331*	2.2
No. of ostial stenting	346*	2.3
No. of occlusion ≥3 mo	943*	6.2
No. of moderate tortuosity	234**	1.5
No. of severe tortuosity	1,471*	9.7
No. of double balloon technique	350***	2.3
No. of double wire technique	140***	0.9

The scores are based on the regression coefficient: a score of 1 has been assigned to the simple lesion coefficient; the other scores are multiples.
r = 0.722; IVUS, intravascular ultrasonography.
*P < 0.001 - **P < 0.05 - ***P < 0.01

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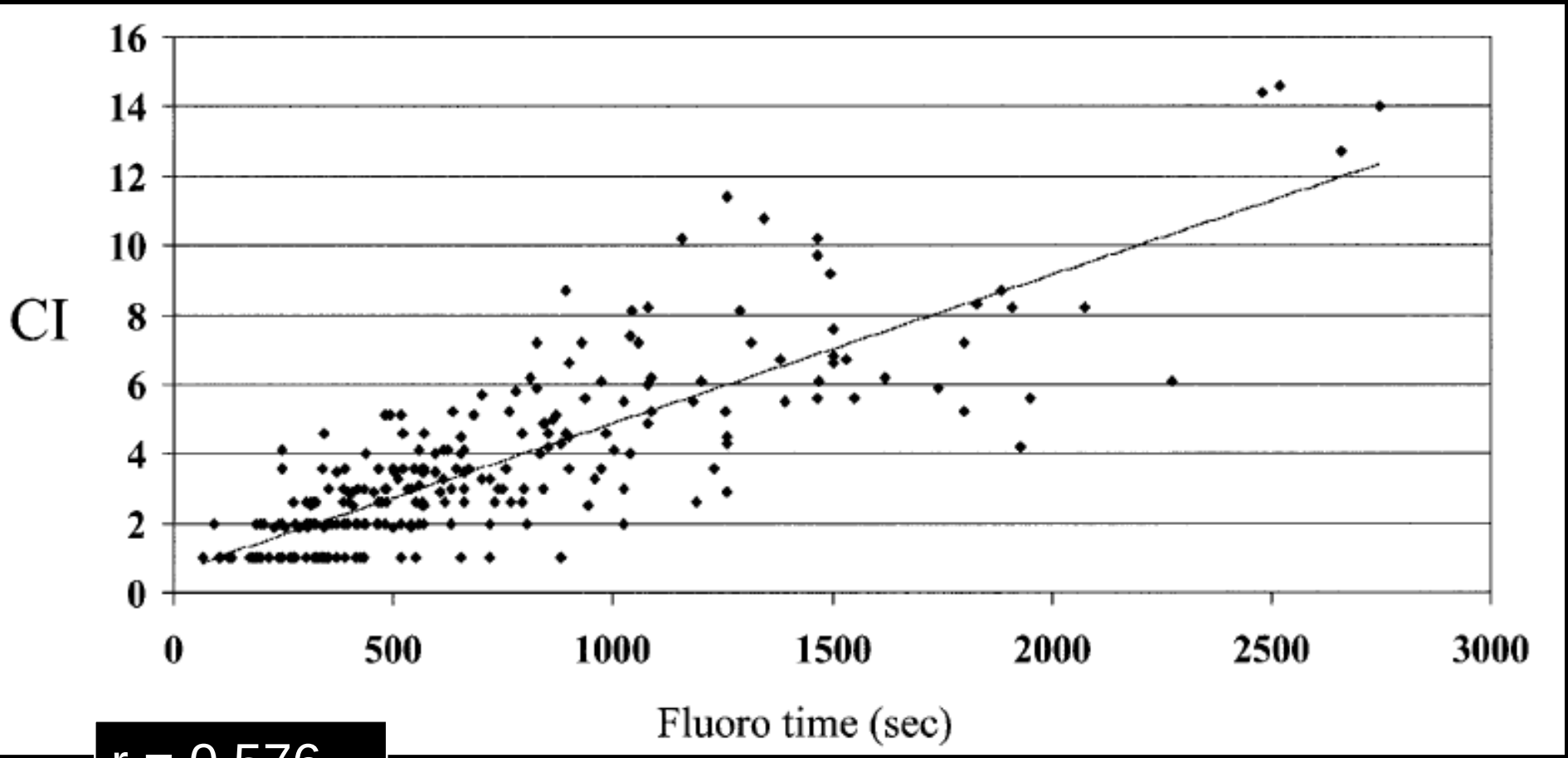
Complexity index/fluoro time correlation

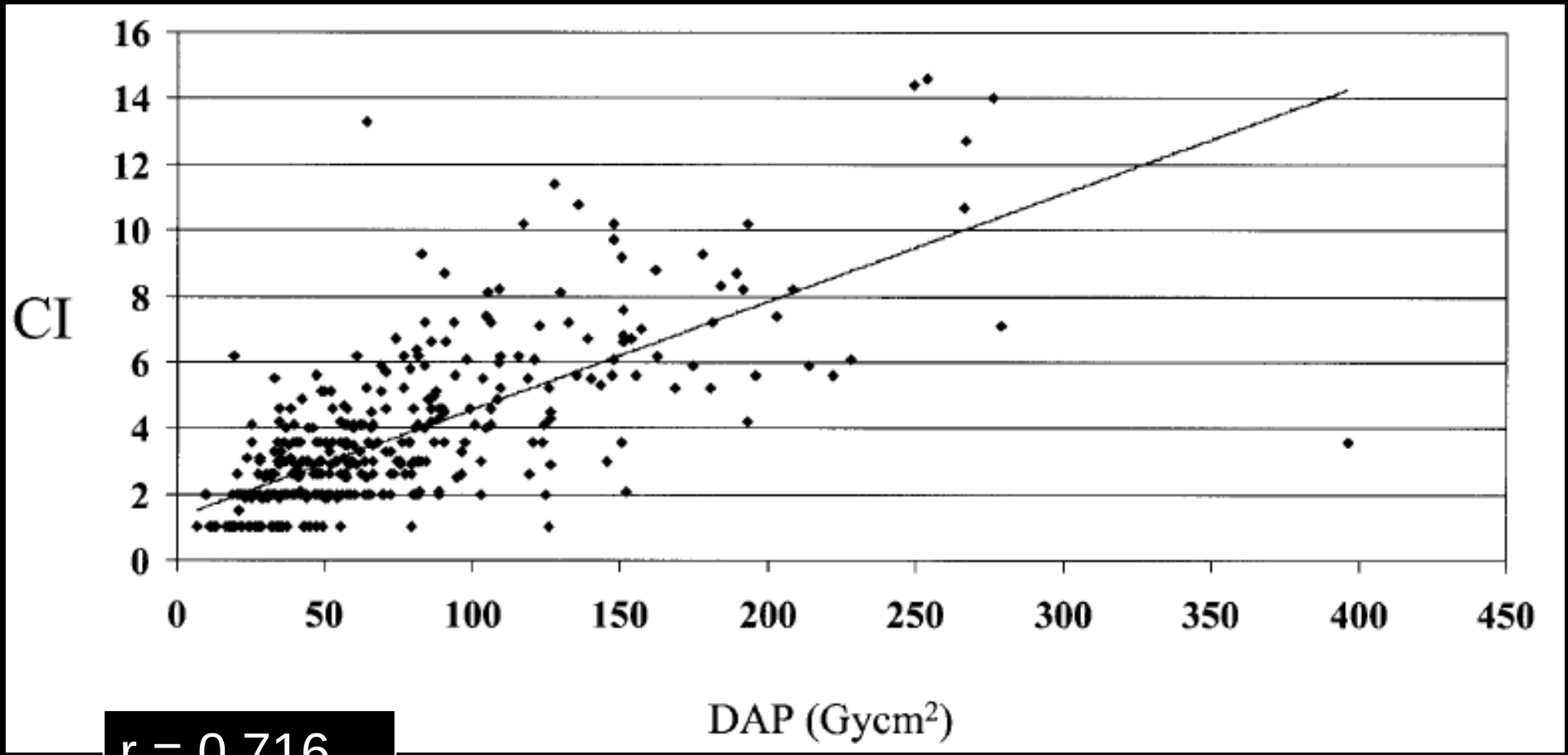
All significant variables



r = 0.576
P < 0.0001

Complexity index/DAP correlation

All significant variables



r = 0.716
P < 0.0001

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most significant & less operator-dependent variables

p< 0.001, p<0.01*, p<0.005°

	Weight (seconds)	score
Constant	159	-
lesion ≤ B2 (AHA)	151	-
lesion > B2 (AHA)	400	1
IVUS	315	-
simple stenting	157	-
bifurcation stenting	331	1,5
ostial stenting	346	0,8
occlusion ≥ 3 months	943	2,8
moderate tortuosity	234°	-
severe tortuosity	1471	4,9
double balloon technique	350*	-
double wire technique	140*	-

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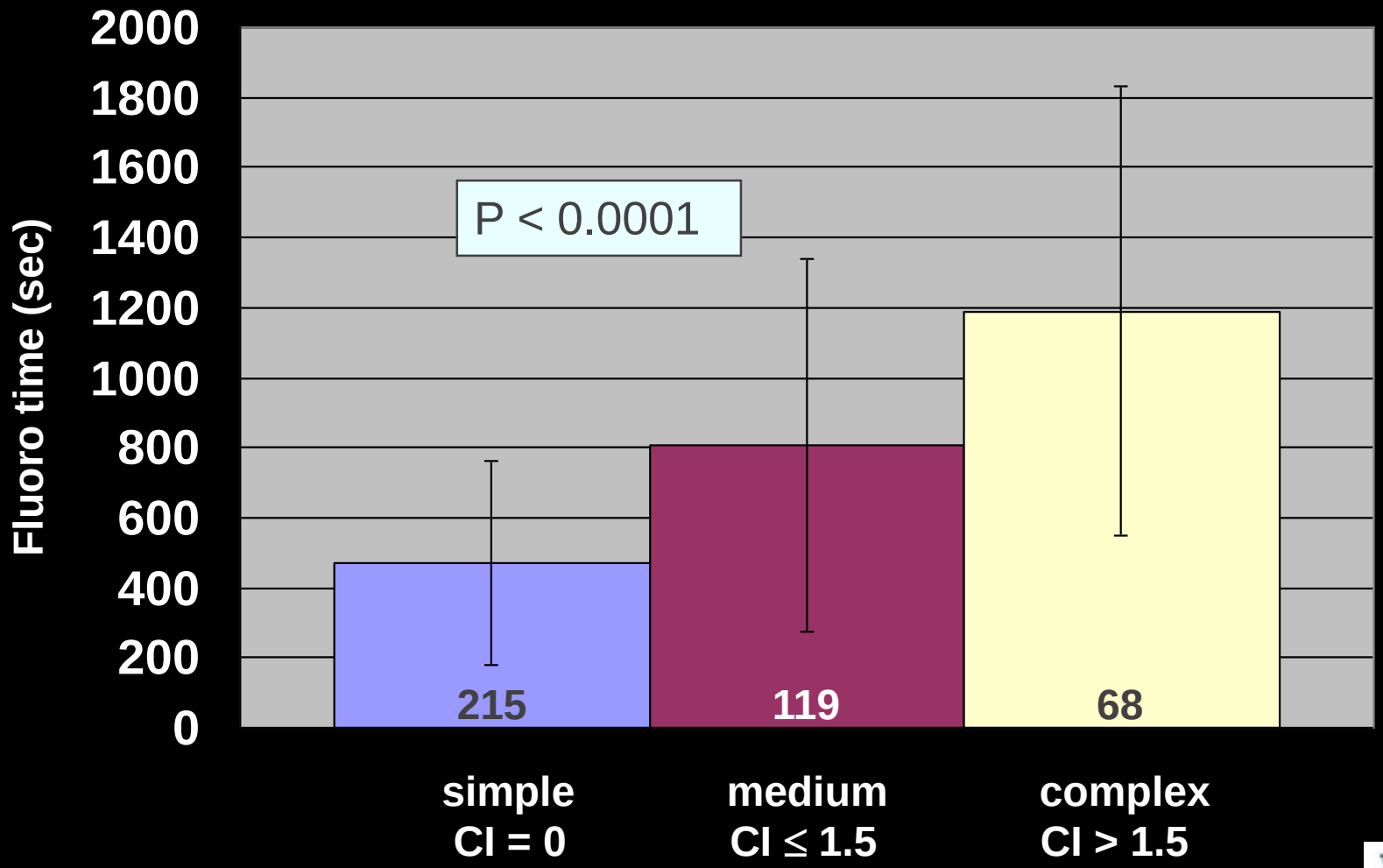
complexity index-based stratification

fluoro time



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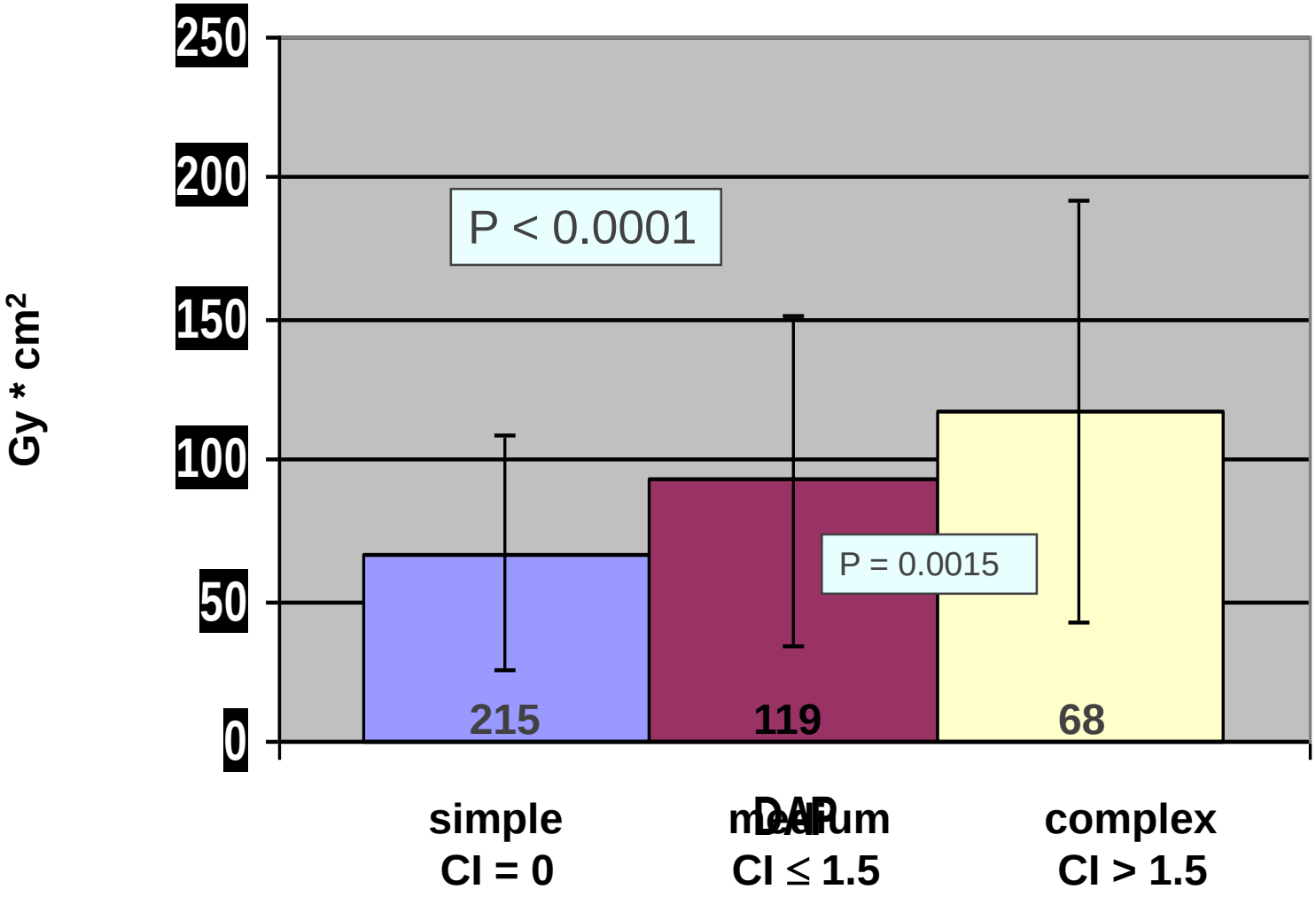
complexity index-based stratification

total DAP



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complexity index-based stratification

Fluoro time and total DAP, (Chile, Italy, Spain, Uruguay, USA, 857 procedures)

All PTCA (857 cases)	Multivessel	Lesion type	Occlusion >3 months	Severe tortuosity	Bifurcation stenting
No. of cases	117	161	24	25	58
Coefficients (min)	9.75	4.98	7.20	6.77	5.66
(p value, 2 tail)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)
Weighting factors for the complexity index	1	0.51	0.73	0.69	0.58

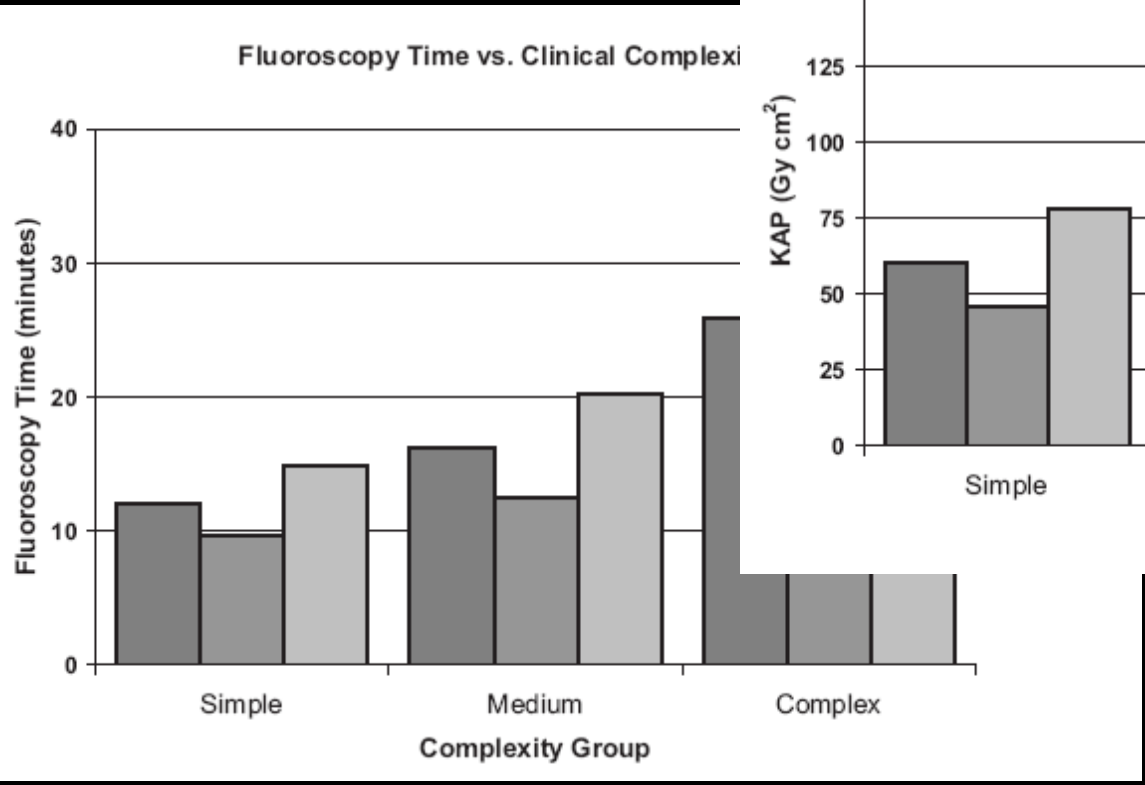
N=857 cases

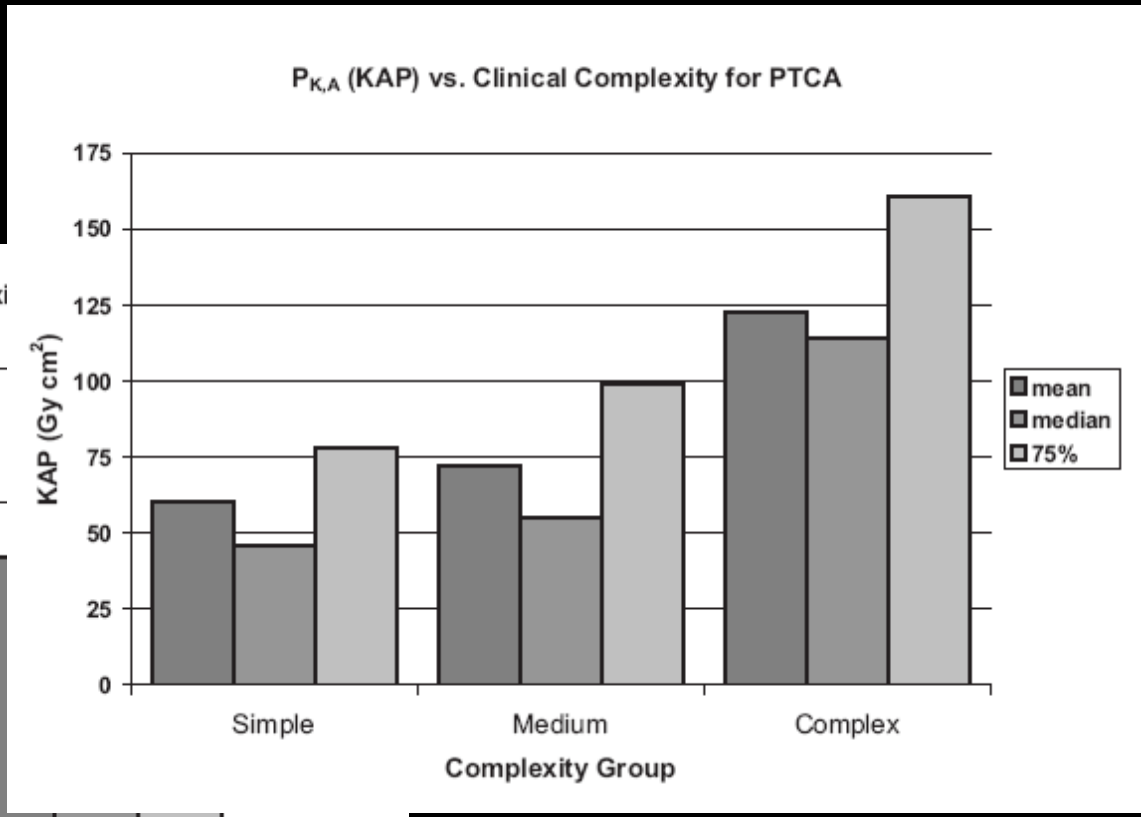
Other factors, such as ostial stenting and interventions in bypass grafts did not enter the regression, possibly due to insufficient numbers of procedures in our series

Balter, Medical Physics 2008

complexity index-based stratification

Fluoro time and total DAP, (Chile, Italy, Spain, Uruguay, USA, 857 procedures)





Balter, Medical Physics 2008

- Complexity of percutaneous coronary interventions (PCI) can be assessed in an objective manner
- A scoring system can be developed and a Complexity Index (CI) can be calculated
- Based on CI, PCI can be divided into groups significantly different in terms radiation exposure parameters
- The factors that determine the CI can change over time and in different centers

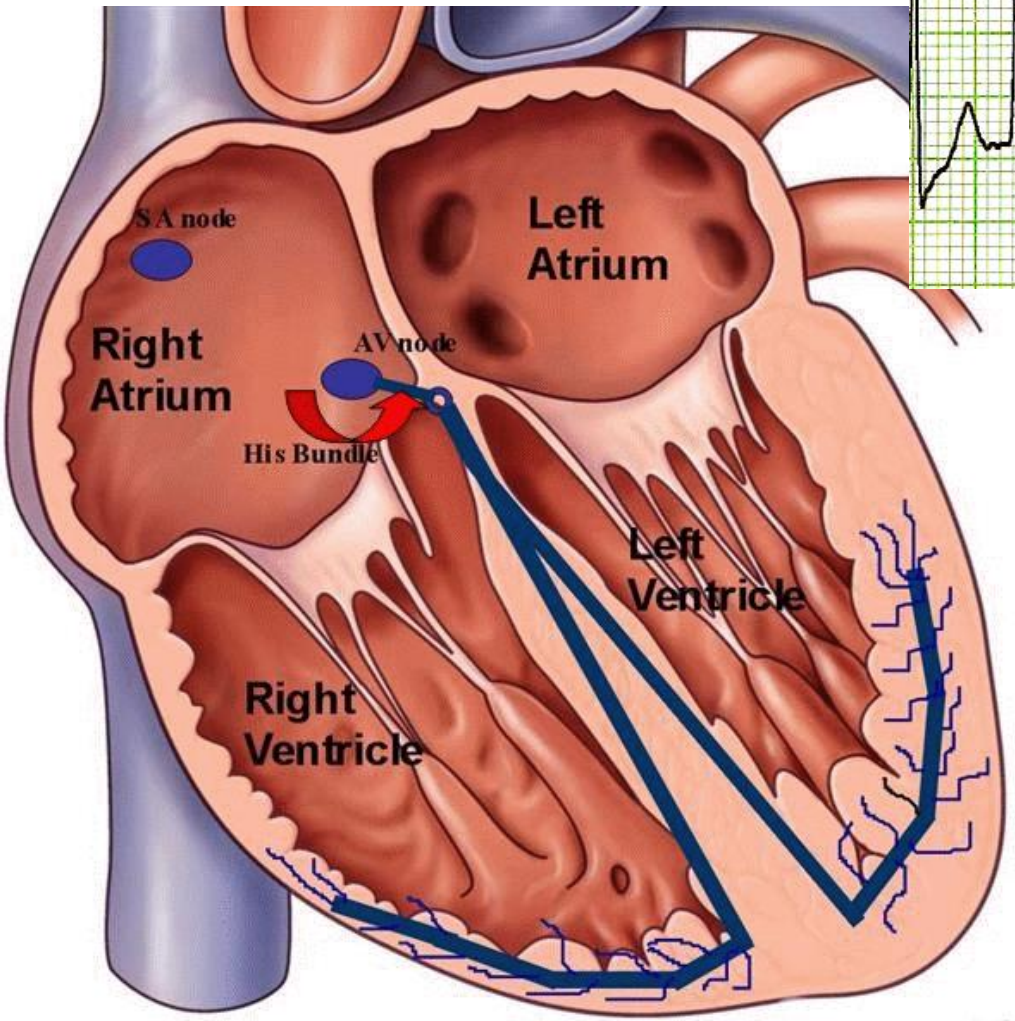
Electrophysiology

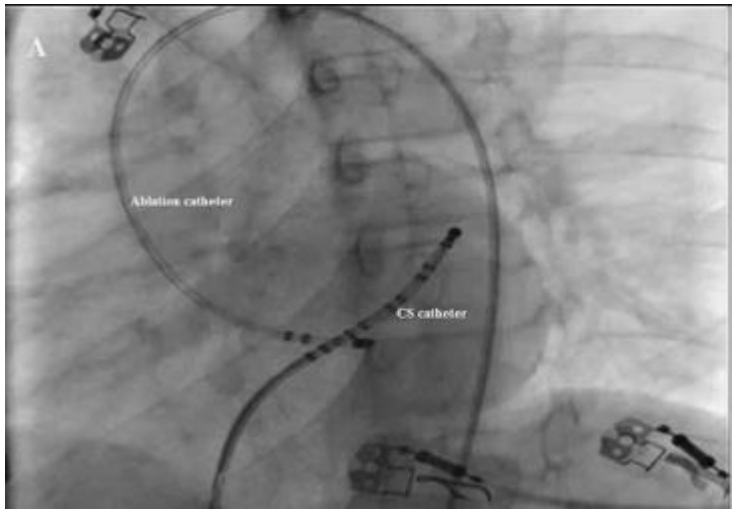
diagnostic & interventional

- ✓ EP diagnostic studies
- ✓ Pacemaker implantation
- ✓ Automatic implantable cardioverter defibrillator (AICD)
- ✓ Arrhythmias ablation
  - ✓ Accessory pathways
  - ✓ Atrial fibrillation/flutter
  - ✓ Ventricular tachycardia/VPB

AV Nodal Reentrant Tachycardia (AVNRT)

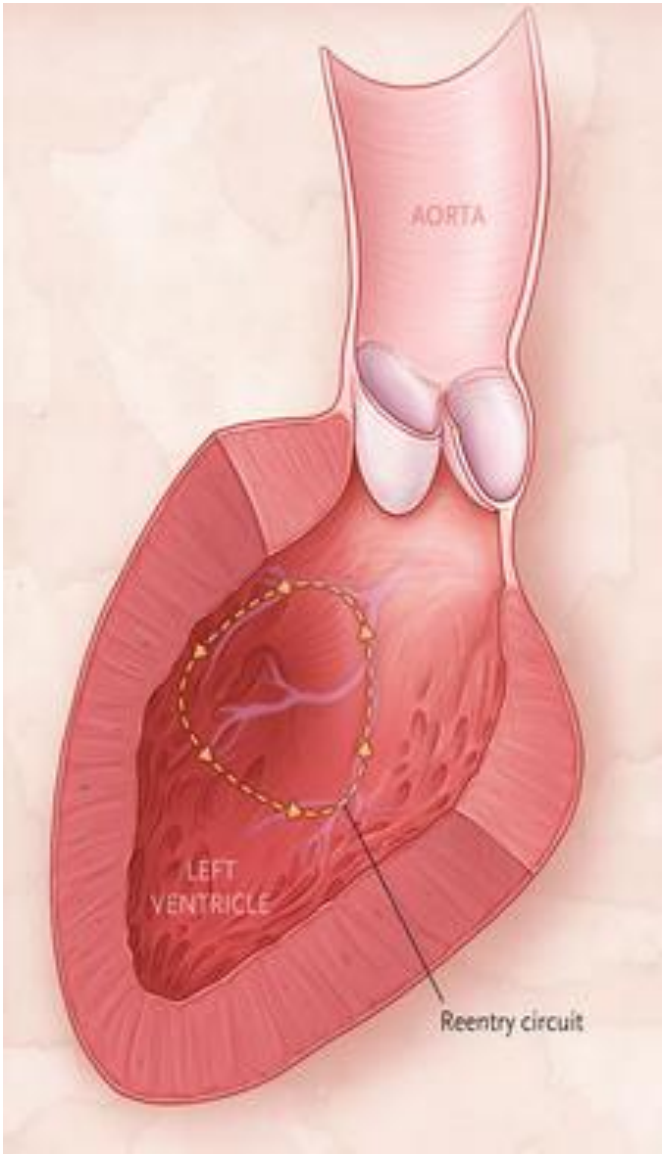
Simple procedure

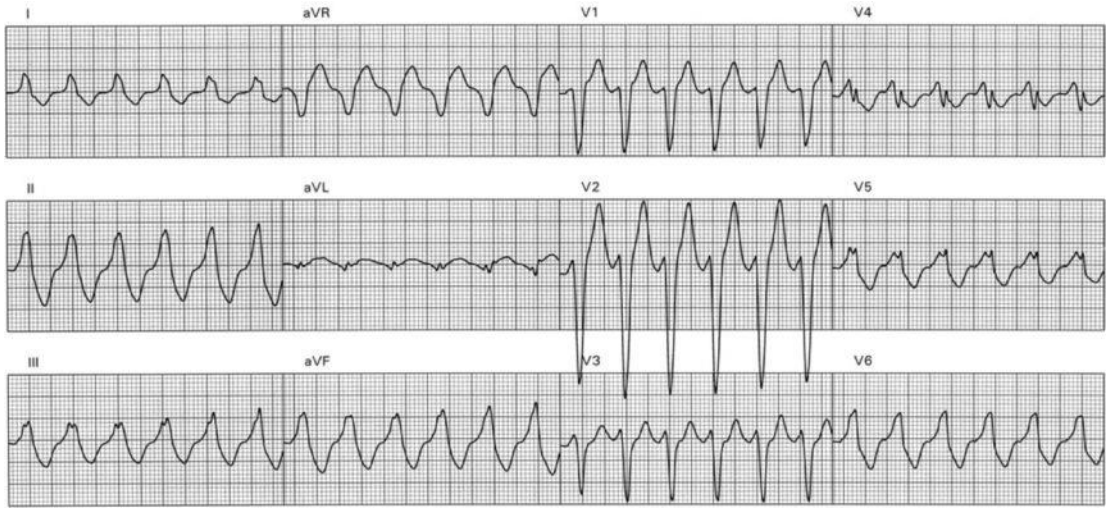




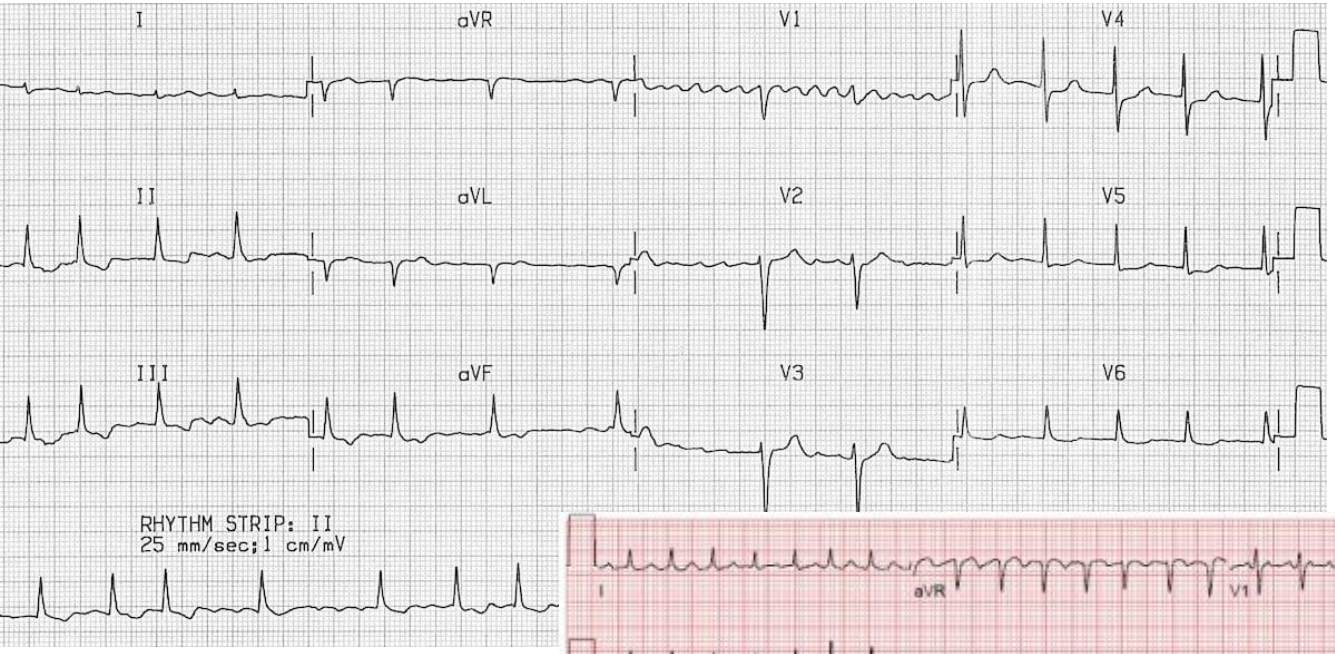
Washington Heart Rhythm Associates, LLC

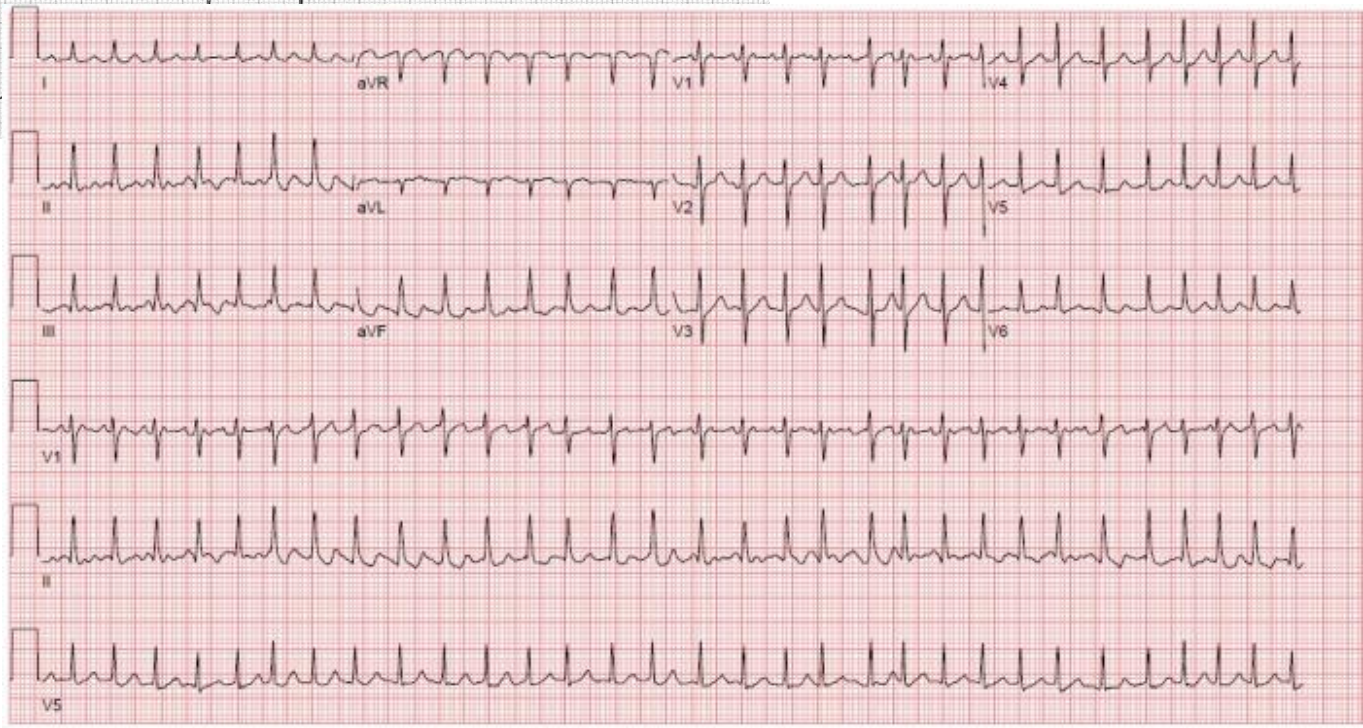
Reentrant Ventricular Tachicardia



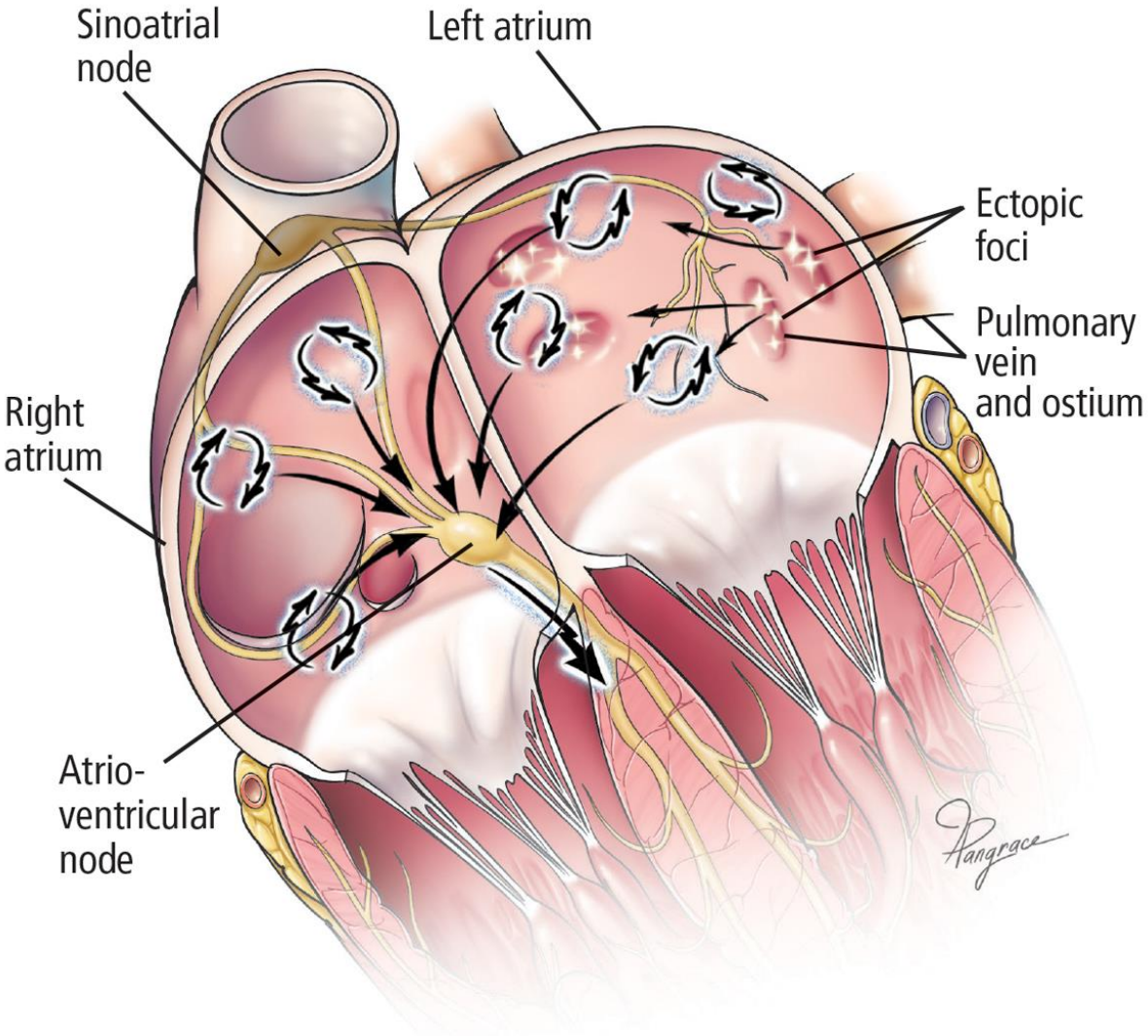


Atrial fibrillation



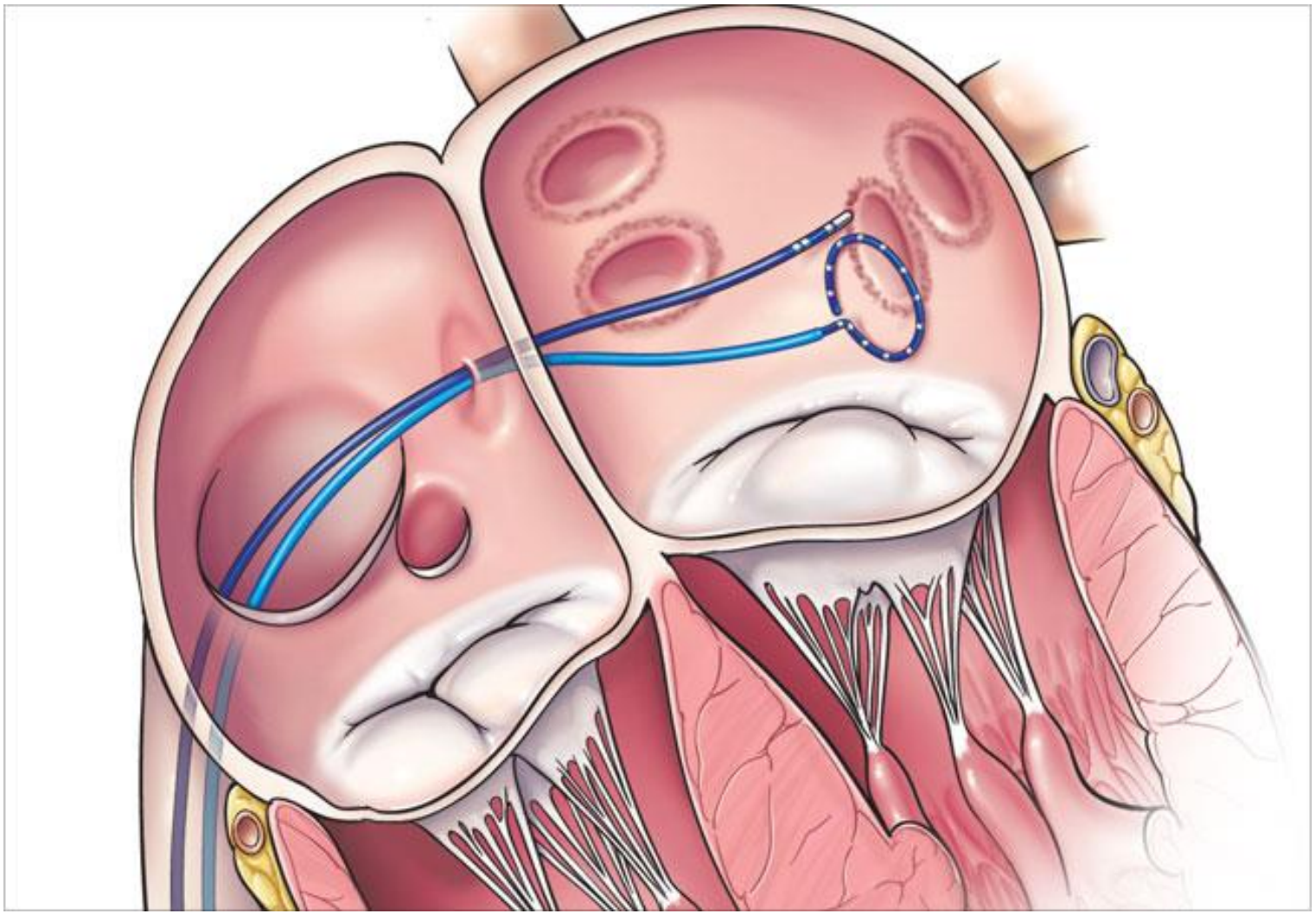


Atrial fibrillation



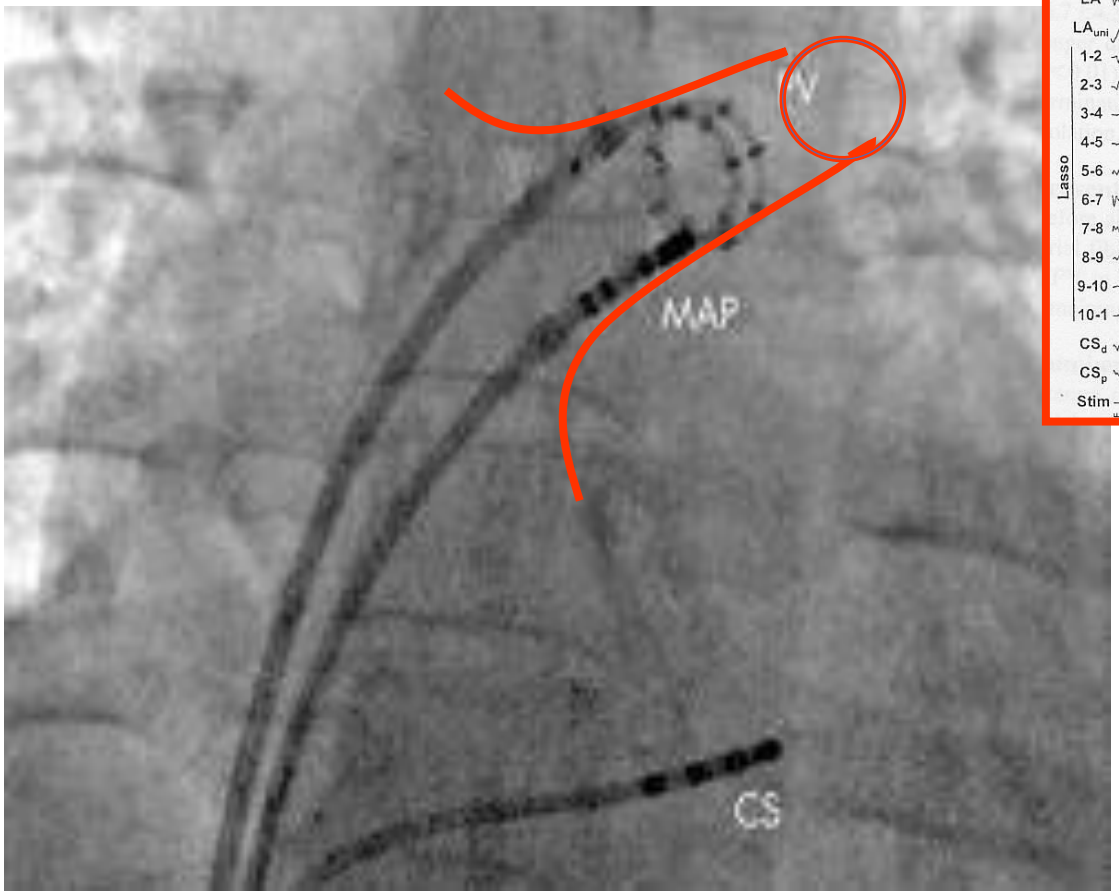
Chowdhury P, Lewis WR, Schweikert RA, Cummings JE. Ablation of atrial fibrillation: what can we tell our patients? Cleve Clin J Med 2009; 76(9)543-550. doi:10.3949/ccjm.76a.08091

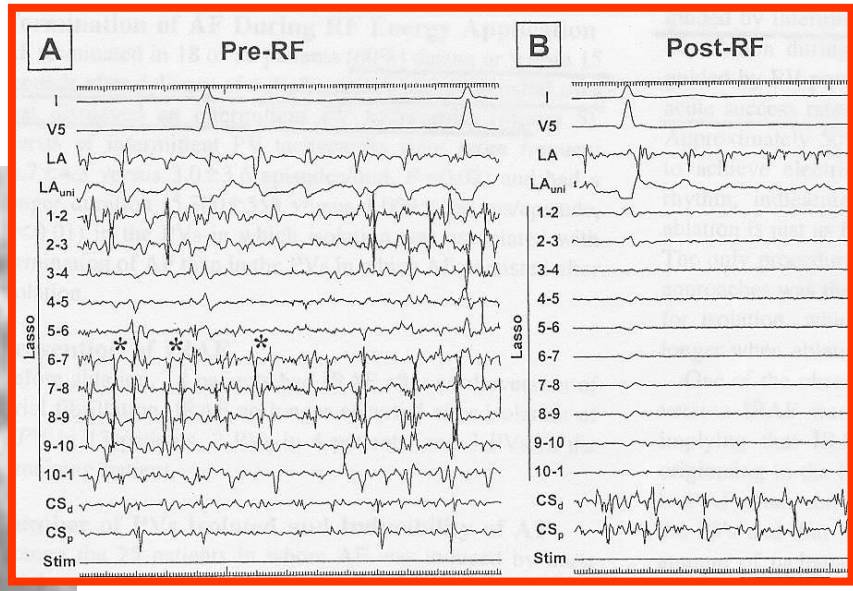
Catheter ablation of atrial fibrillation



Cleveland Clinic

Radiofrequency ablation

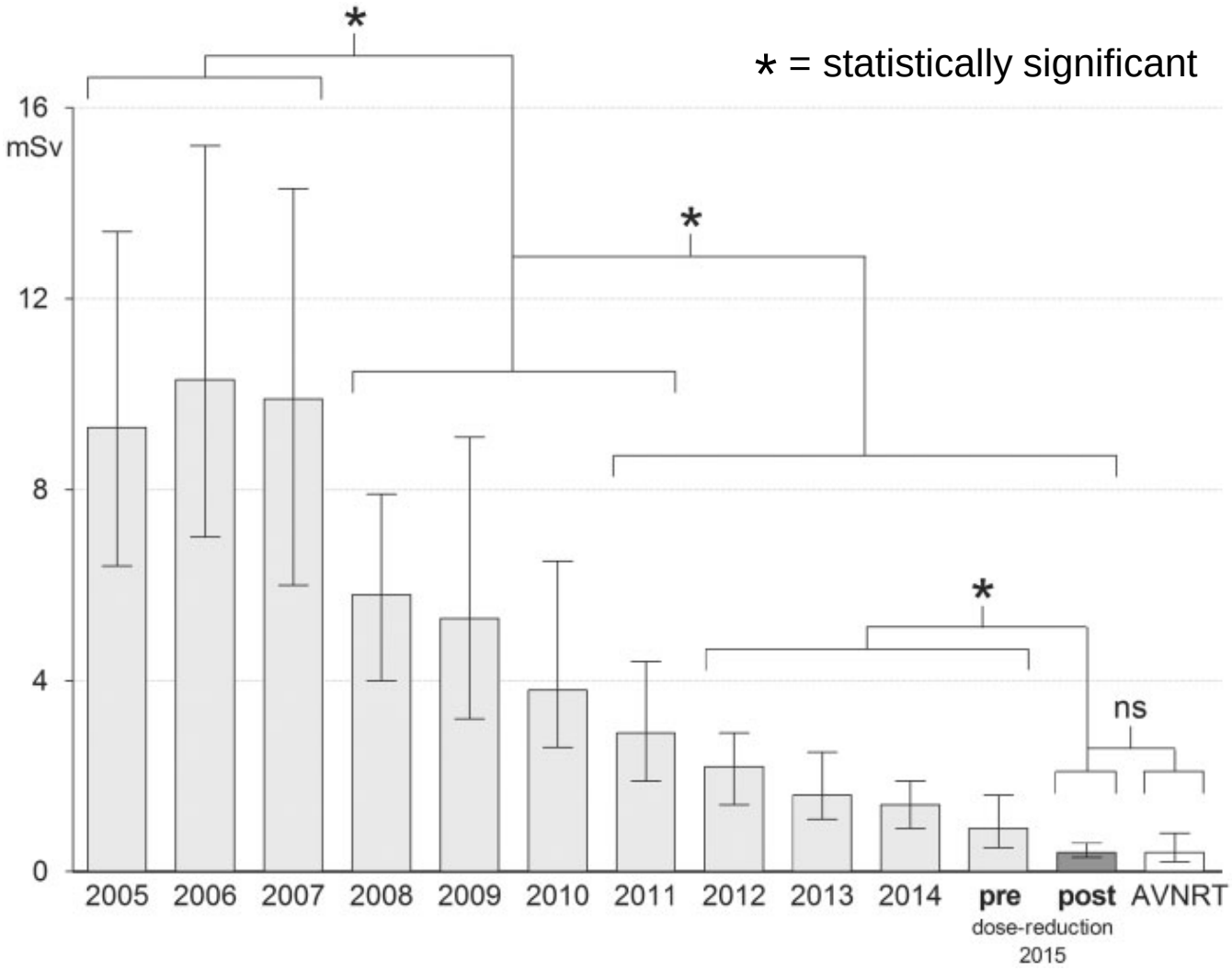




Fluoro time in EP procedures

author	procedure	Fluoro time (m')	reference
Oral H	pulmonary vein isolation	148 ± 34	*Circulation* 2002;105:1077
Oral H	segmental ostial ablation	50 ± 17	*Circulation* 2003;108:2355
Oral H	LA circumferential ablation	39 ± 12	*Circulation*. 2003;108:2355
Haissaguerre M	AF ablation	84 ± 30	*J Card Electr* 2005;16:1125
Saliba W	AF ablation with robotic navigation	64 ± 33	*JACC* 2008;51:2407
Pappone C		32.3 ± 11	*JACC* 2006;47:1390
Schwartzman D	AF ablation ICE & 3D mapping	6 ± 2	*Heart Rhythm* 2006;3:930

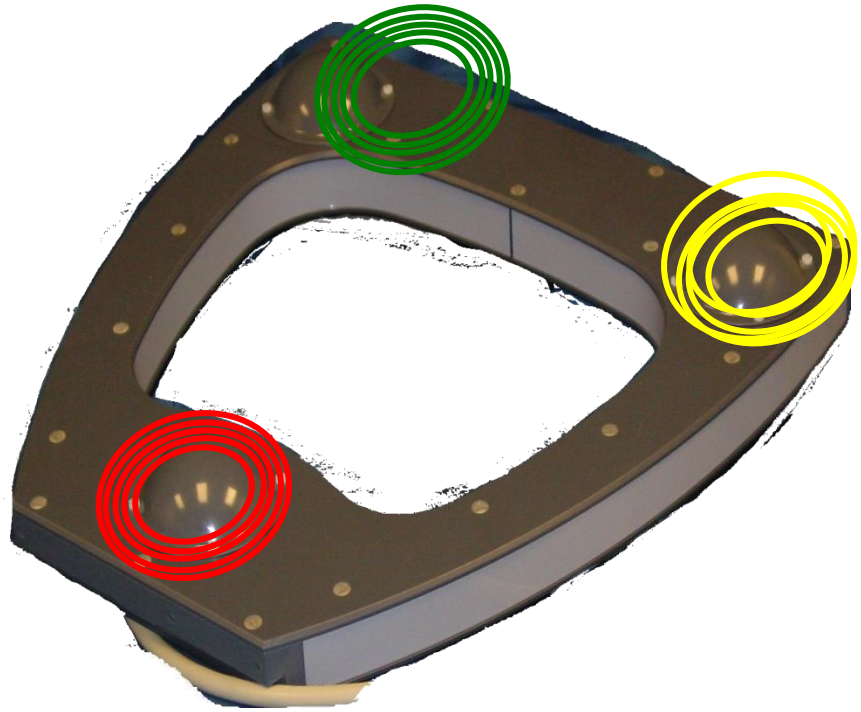
Radiation dose during PVI over time



Lehrmann H, Europace 2018;20:279

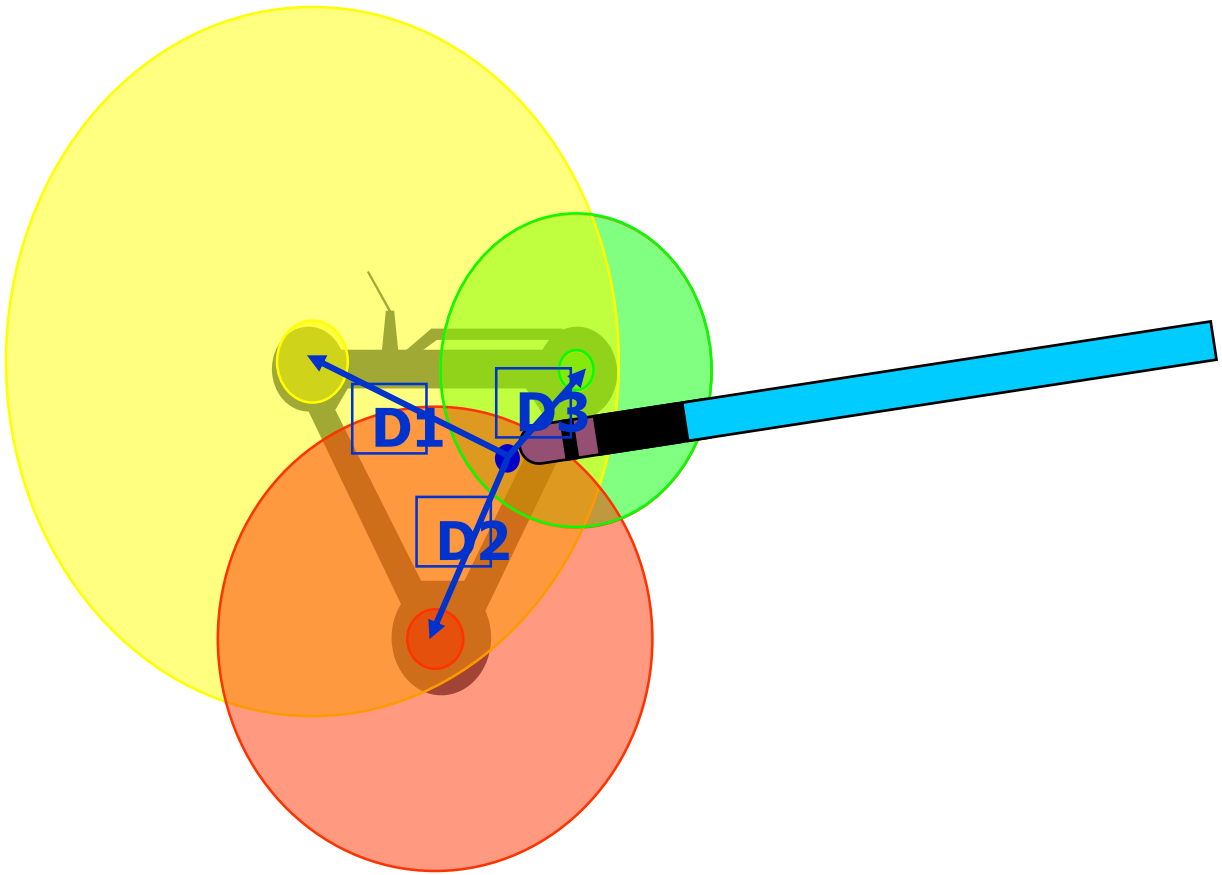
The location pad

Generator of a low-intensity magnetic field



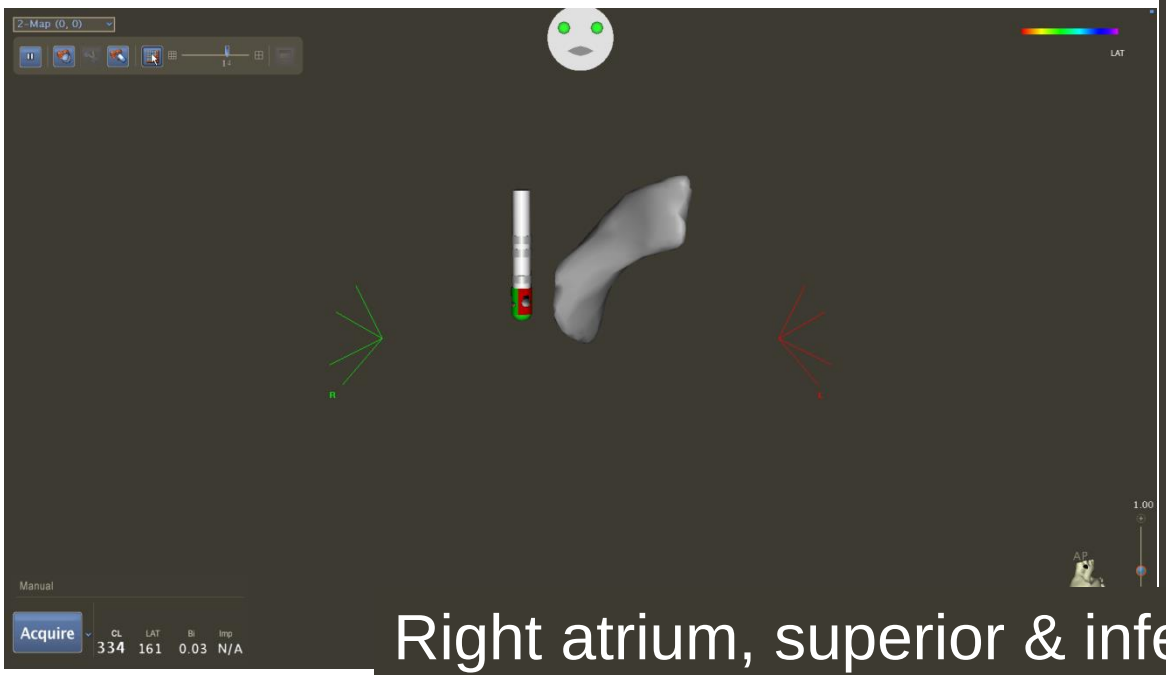
Localization of a sensor

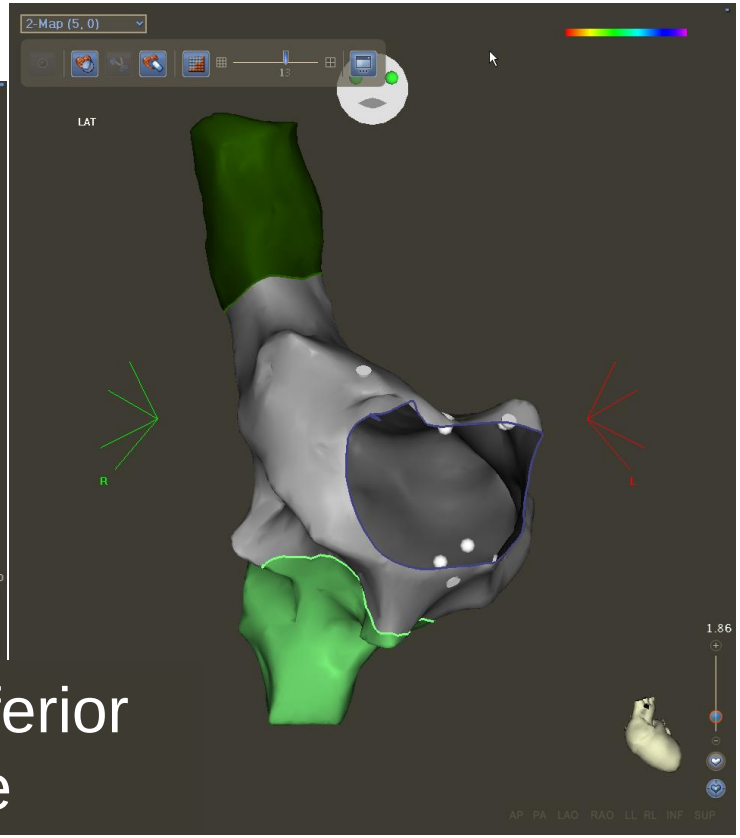
The magnetic field is able to detect the position of the tip of a dedicated catheter



CARTO maps

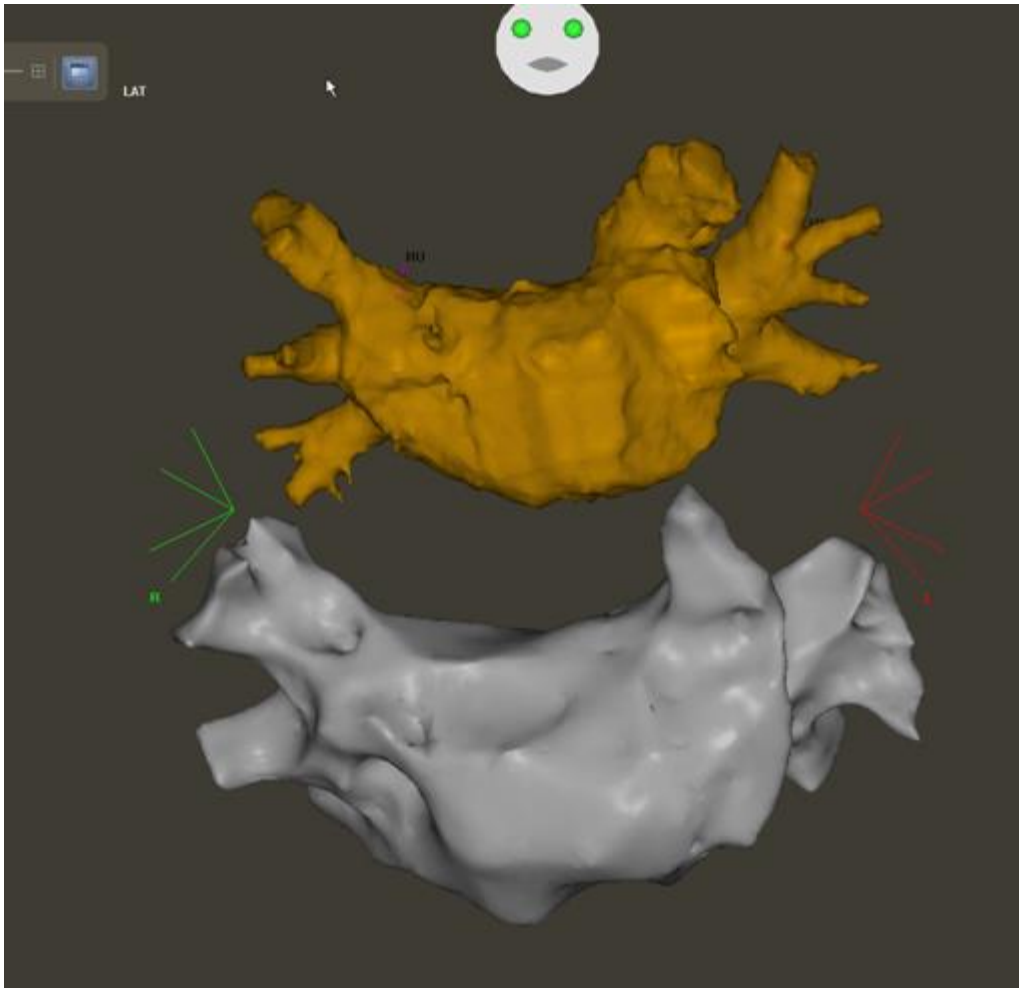
A cardiac map is generated by moving the catheter inside the cardiac chambers





Right atrium, superior & inferior vena cava, triucuspid valve

Merging CARTO maps with CT/MR



Left atrium, pulmonary veins & LAA

Classification of complexity in EP

Complex ablation

- Atrial fibrillation
- Atypical atrial flutter/tachycardias
- Ventricular tachycardia
- Pts with complex congenital heart disease

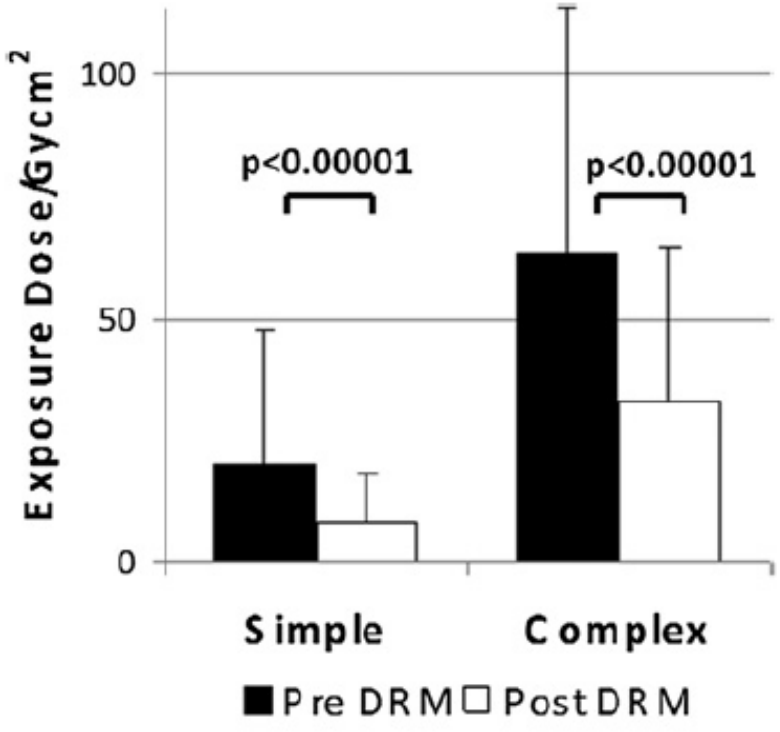
Simple ablation

- Accessory pathway
- Atrioventricular nodal re-entry tachycardia
- Typical caval-isthmus dependent atrial flutter
- Atrioventricular nodal ablation

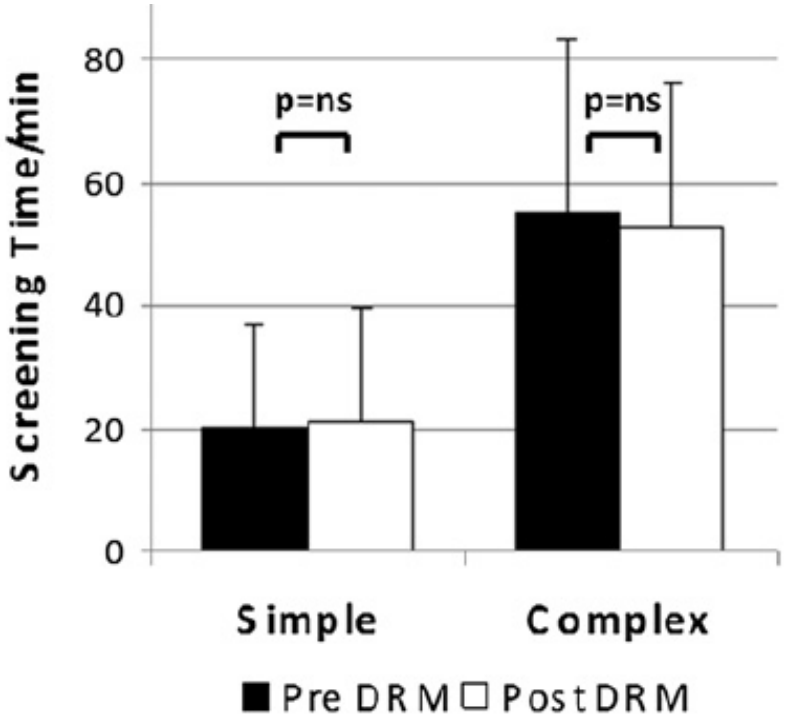
Rogers DPS, Heart 2011;97:366

Effect of simple radiation dose reduction strategy in complex & simple EP procedures

Exposure dose



Screening time



DRM: dose reduction manoeuvres

Baseline fluoro 'low' → 12.5 pps pulse length of 6 ms grid in situ

Customised 'ultra-low' fluoro → 6.25 pps grid removed

Rogers DPS, Heart 2011;97:366

Conclusions

- Cardiac FGI procedures highly contribute to patients' exposure
- Procedures' complexity plays a major role in the exposure rate
- Complexity needs to be known, measured and reviewed over time
- Further research is to be done in assessing complexity in new fields of FGI

the end

thanks for attention