

# Aplicaciones del

Intra

Vascular

Ultra

Sound

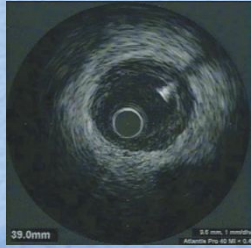
## en el laboratorio de Hemodinámica

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Complejo Hospitalario de Toledo

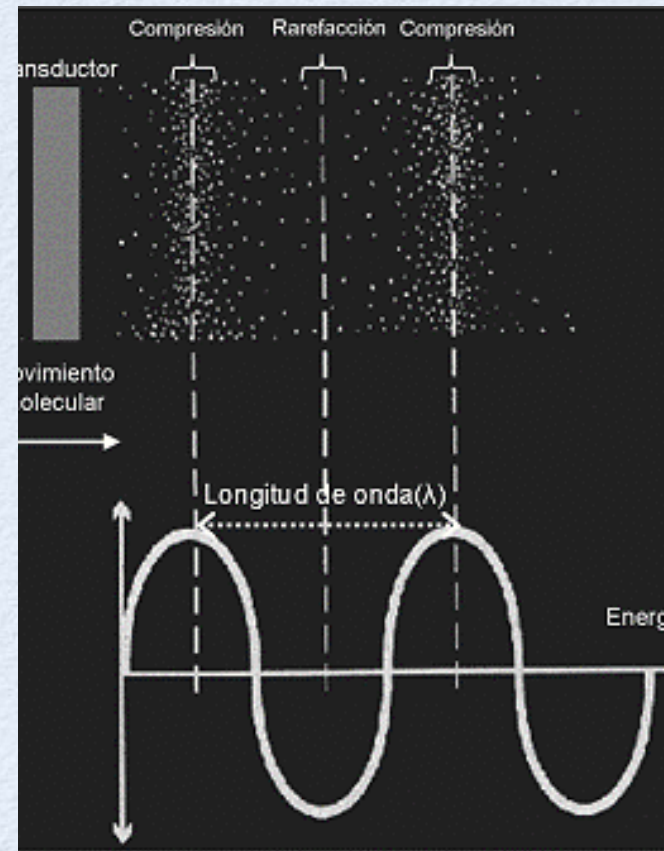
# Índice

- Conceptos básicos:
  - Fundamentos físicos
  - Imágenes
  - Medidas más frecuentes
- Métodos de imagen intracoronaria
- Utilidad del IVUS en el laboratorio de hemodinámica
  - Estudio de la placa aterosclerótica.
  - Como guía en la ICP
  - Valoración de stent
- Evidencia científica
- Guías de práctica clínica
- Conclusiones

# Algo de física

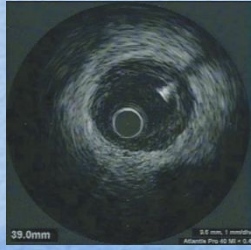


- Ultrasonido: frecuencia superior al umbral de audición humano (>20 KHz)
- Origen: efecto piezoeléctrico
- Representación como onda sinusoidal:
  - $V = f * \lambda$
  - $f = V/\lambda$
- Formación de eco: depende de las propiedades acústicas del medio (resistencia al paso de ultrasonidos de un medio a otro = impedancia acústica)
  - Materiales sólidos de alta densidad (calcio o metales) : predomina la reflexión, formación de “sombra acústica”
  - Gas: predomina dispersión, prácticamente sin ecos ni penetración.
  - Tejidos blandos y fluidos: menor reflexión y atenuación = mayor penetración.
- Mayor frecuencia = más resolución/menos penetración
- Estudio intracoronario: las frecuencias alrededor de 40 mHz mejor equilibrio entre penetración y resolución



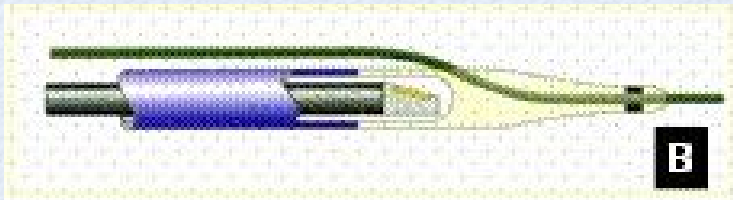


# Imagen

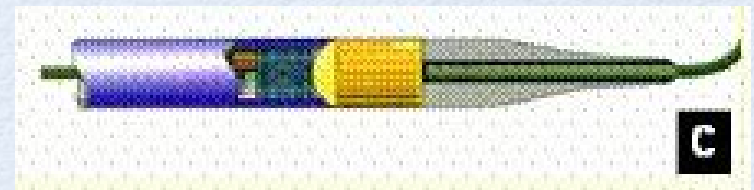


- Cortes transversales: tomografías
- Emisión de US de forma sincrónica en 360°
- Tipos de transductores:

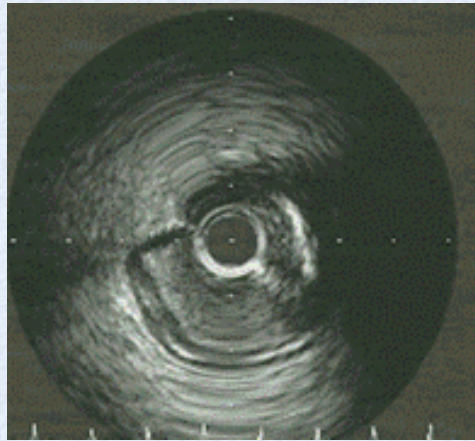
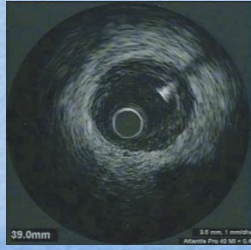
Mecánicos o rotacionales : mayor frecuencia, catéteres más gruesos, artefacto de rotación (NURD), artefacto de guía



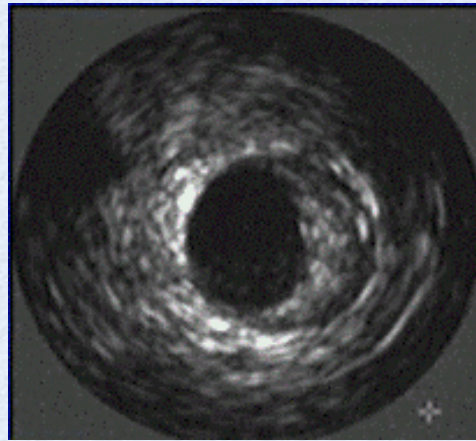
Eléctricos o digitales: artefacto "ring down", permite colorear la señal del flujo sanguíneo



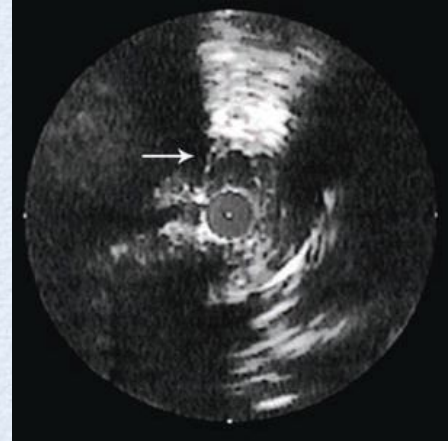
# Artefactos



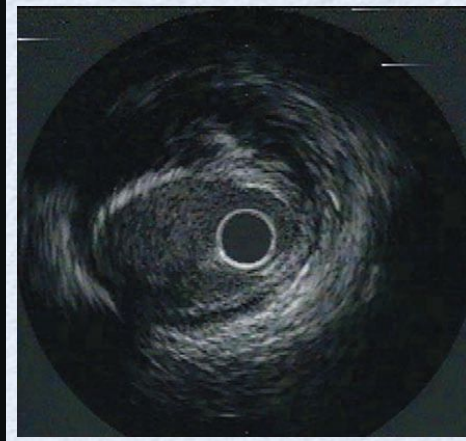
NURD



Ring down



Blood  
speckle

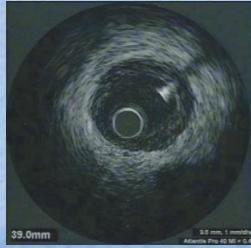


Artefacto  
de  
alineación

Para minimizarlos: correcta alineación de catéter, evitar angulaciones excesivas, válvula hemostática, inyección de contraste

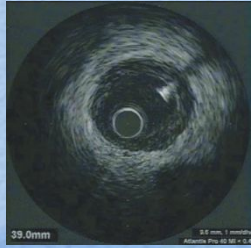


# Imagen



- Calidad:
  - Resolución espacial: axial y lateral. Depende de la frecuencia (para 40 MHz = 150 micras)
  - Resolución por contraste: rango dinámico de escala de grises = capacidad para diferenciar distintos tipos de tejidos (17 - 55 db)

# Imagen: vaso sano



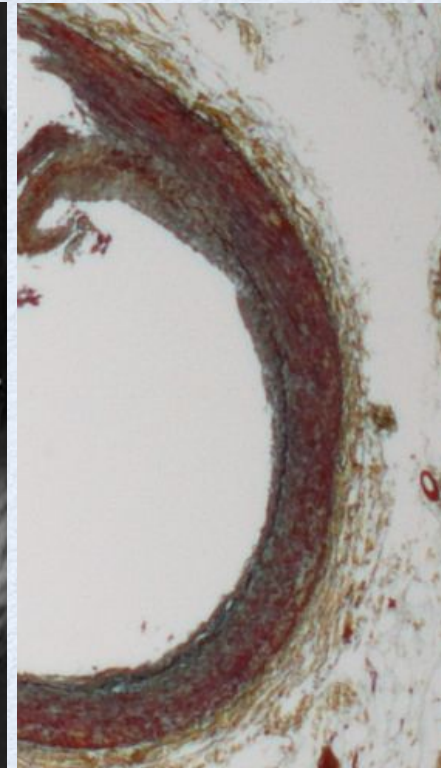
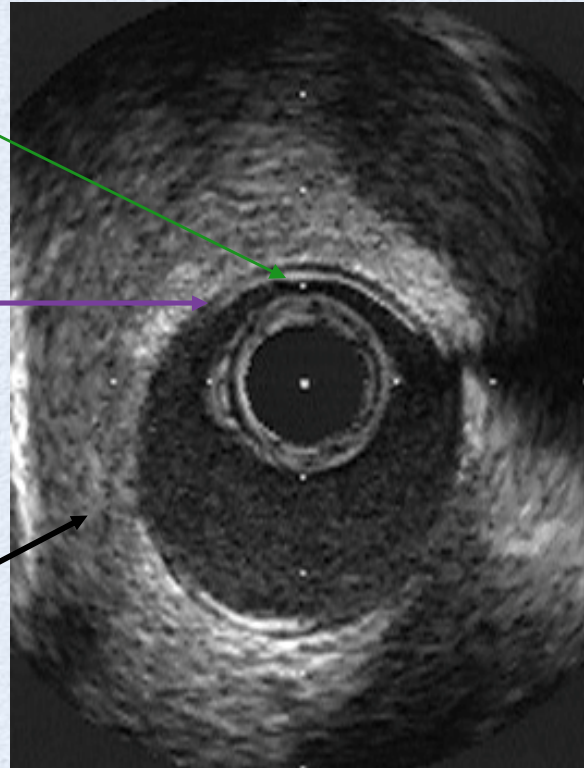
Íntima

Lámina elástica interna

Media

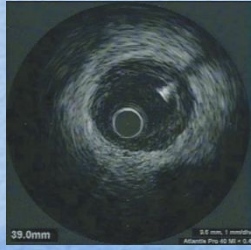
Lámina elástica externa

Adventicia



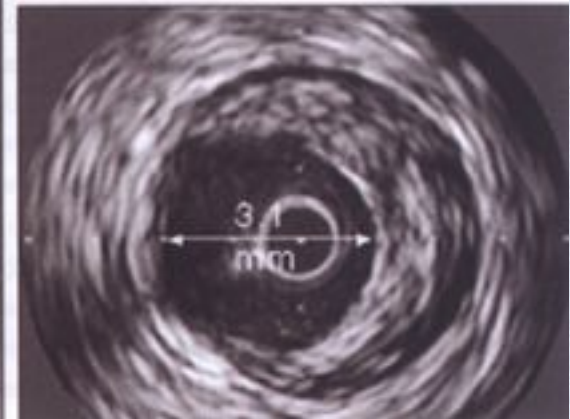
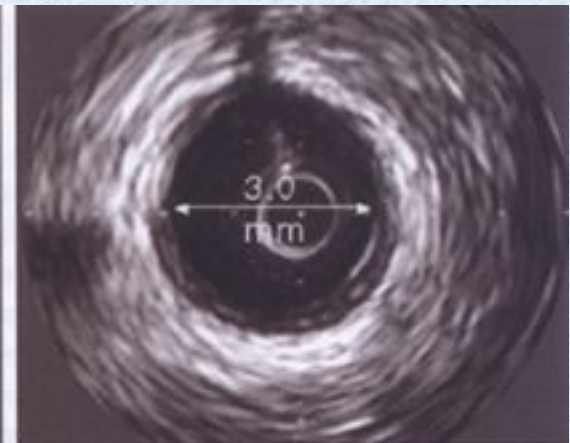


# Patrones de lesión



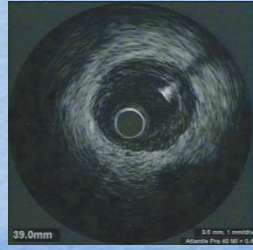
## Remodelado positivo

- Crecimiento excéntrico de placa
- Desplazamiento MEE
- No se modifica luz del vaso
- Estadios iniciales

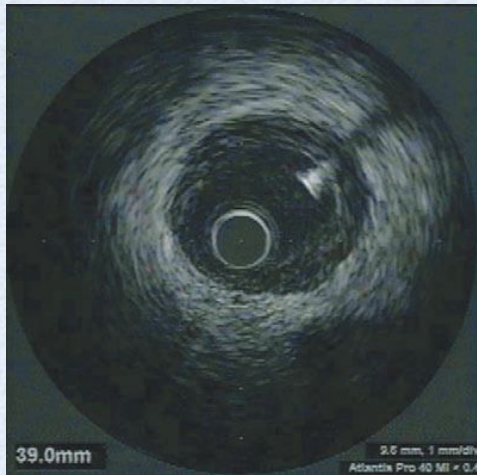




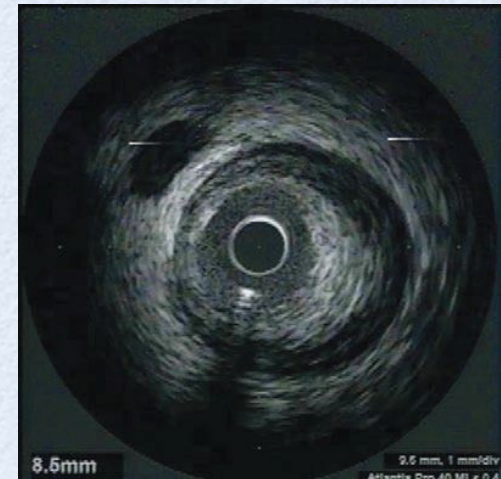
# PATRONES DE LESIÓN



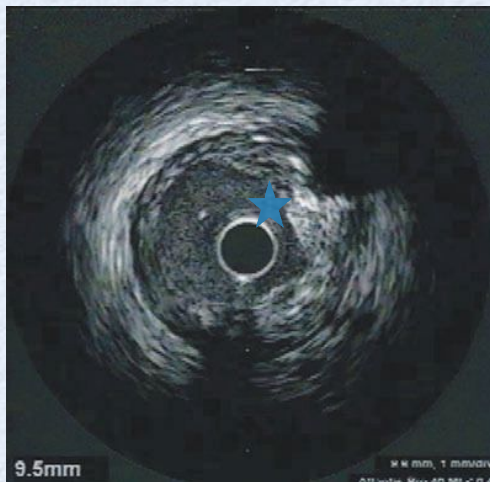
Placa blanda



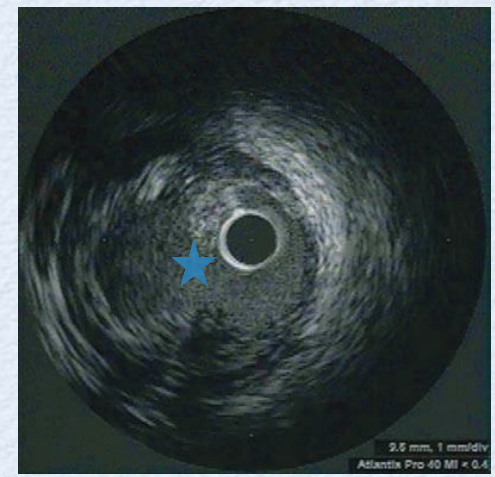
Placa fibrosa



Placa calcificada

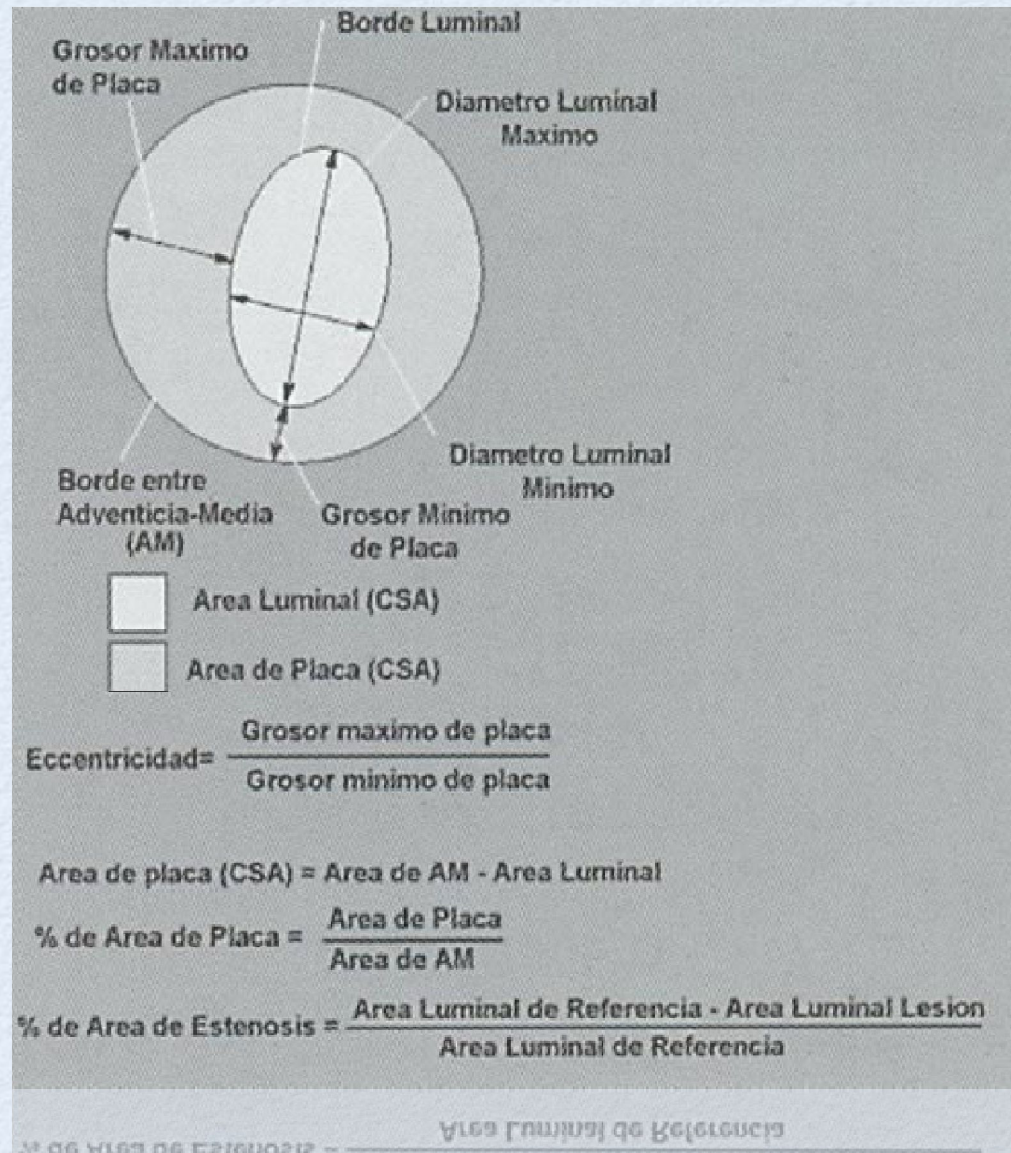


Placa complicada



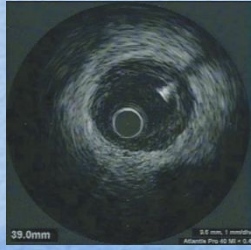


# Medidas

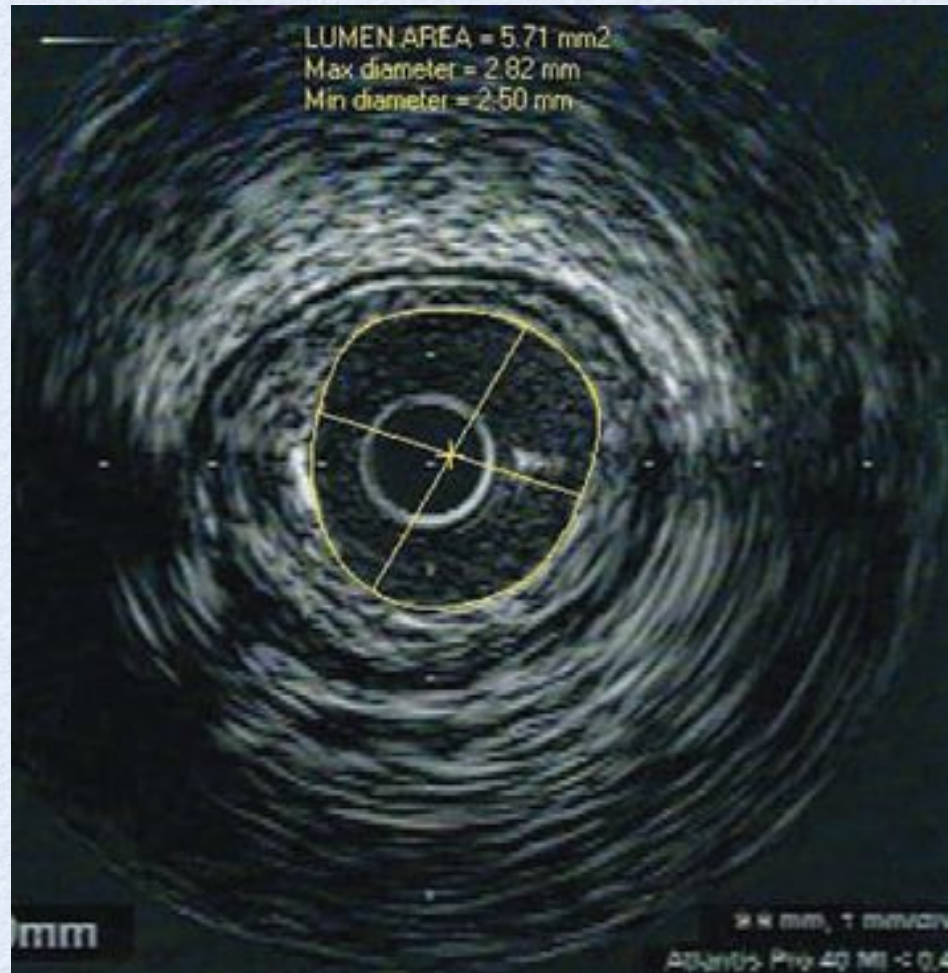




# Mediciones 1

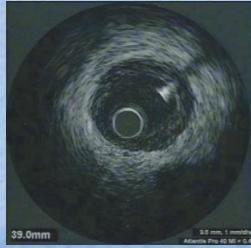


- Área luminal mínima (ALM)
- Diámetro luminal mínimo (DLM)

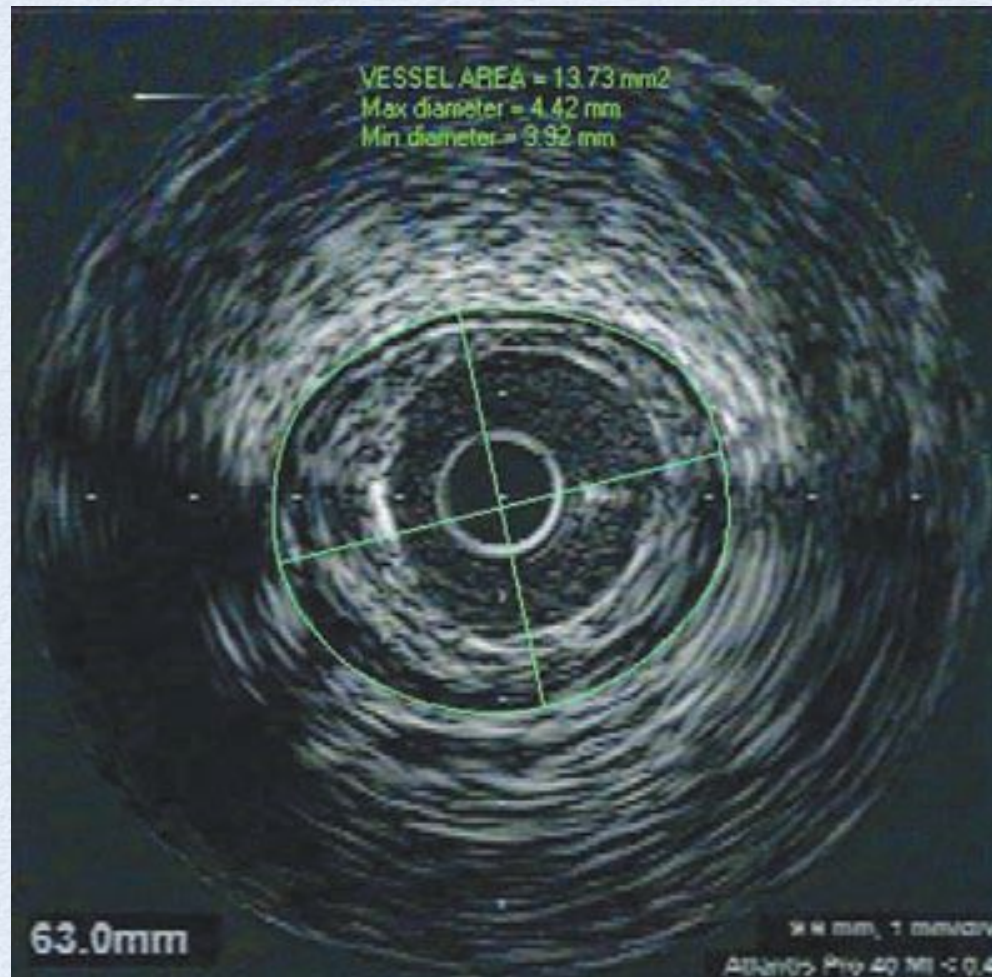




# Mediciones 2

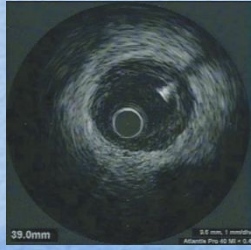


Área del vaso (EEM)  
Diámetro del vaso

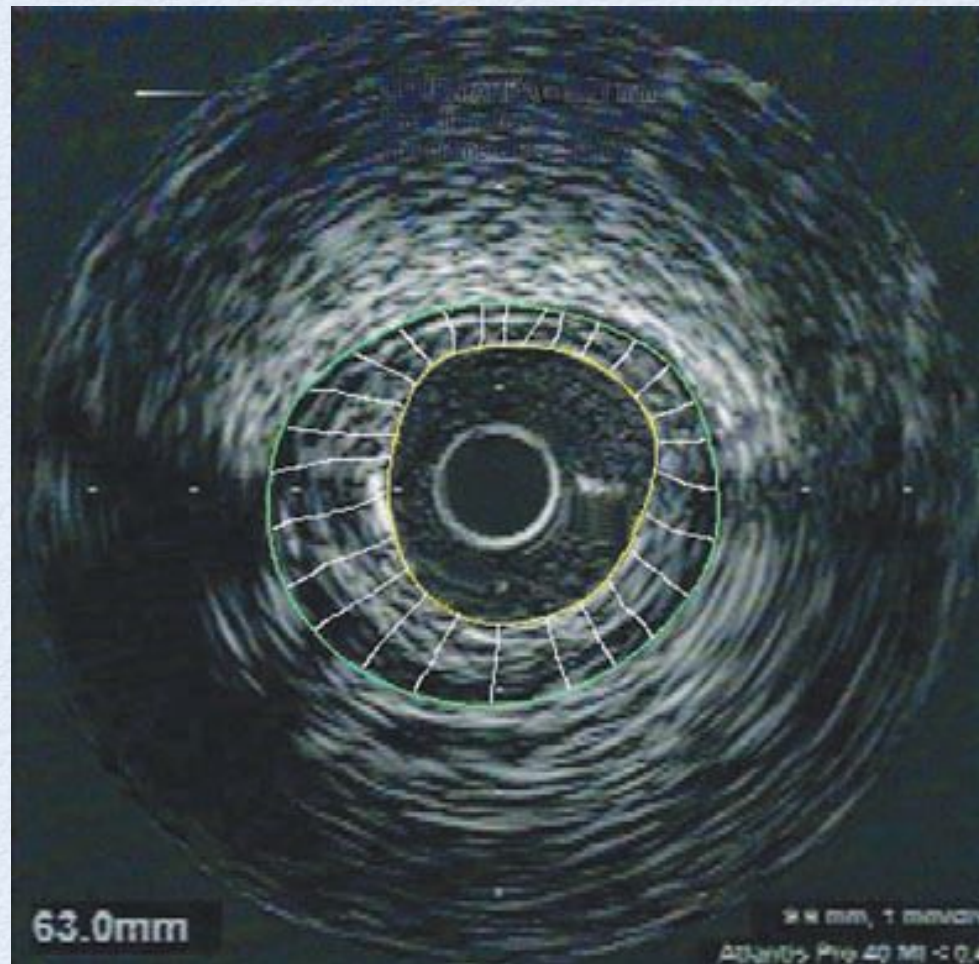




# Mediciones 3

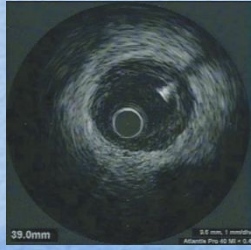


$$\text{Área de placa} = \text{EEM} - \text{ALM}$$





# Mediciones 4



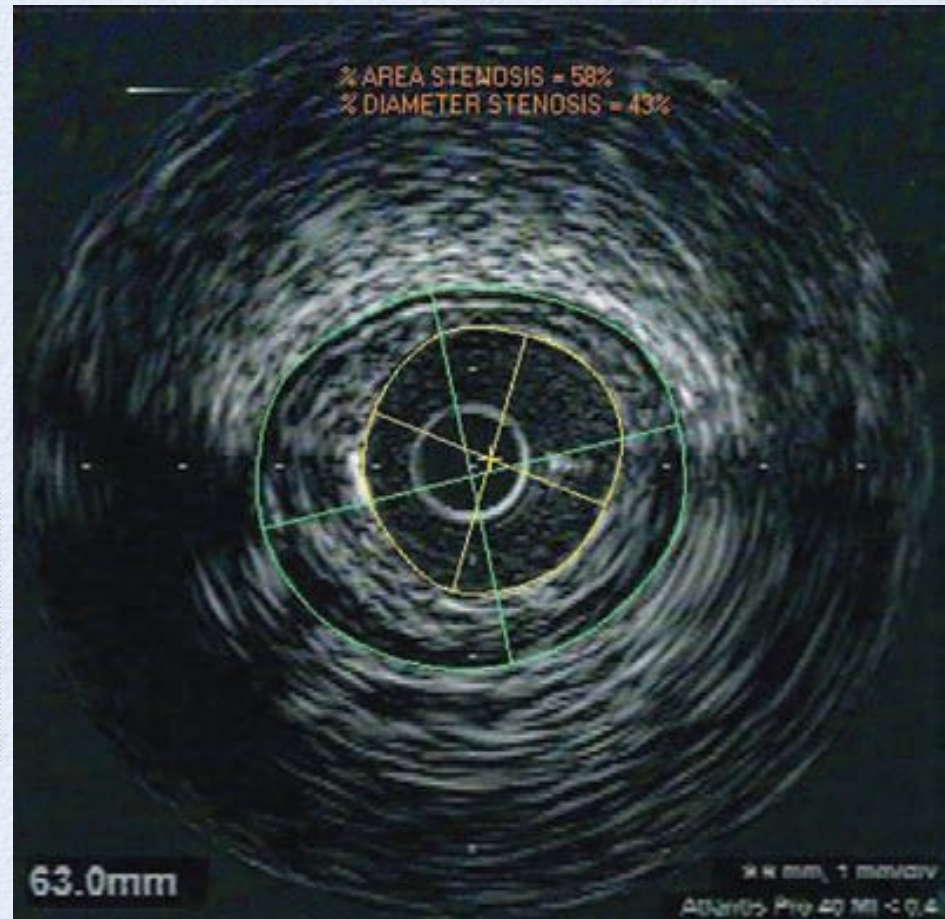
## Grado de estenosis %

$$\% \text{Área} = \text{EEM-ALM/EEM}$$

$$\% \text{Diámetro} = \text{DV-MLM/DV}$$

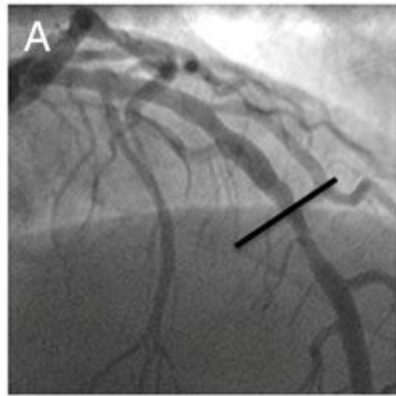
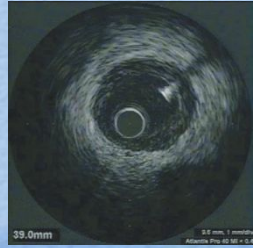
$$\% \text{Área} = \text{ALref-ALMin/ALref}$$

$$\% \text{Diámetro} = \text{DLr-DLMin/DLref}$$

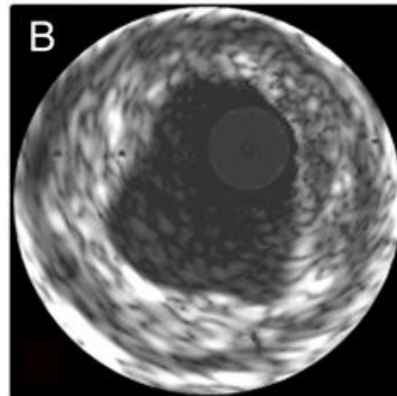




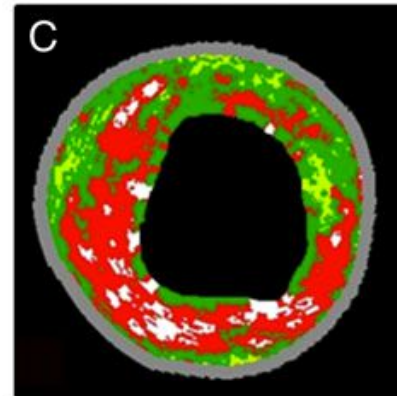
# Métodos de imagen



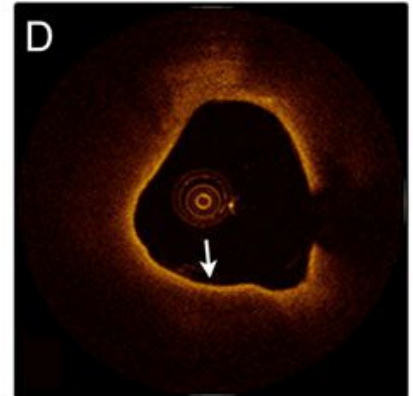
Lumen stenosis  
**Angiography**



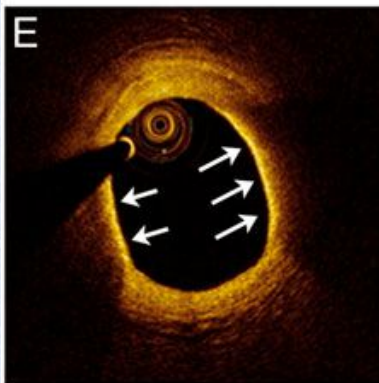
Atheroma / Vessel wall  
**IVUS**



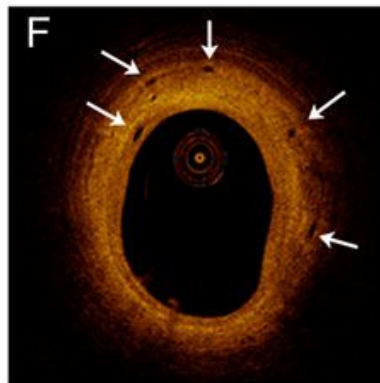
Plaque composition  
**IVUS-VH**



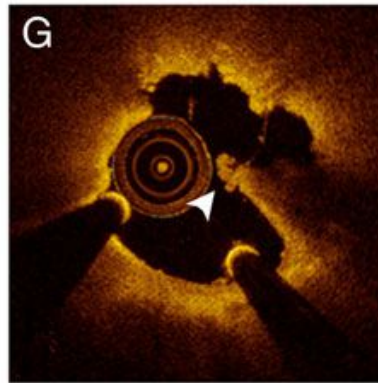
Thin fibrous cap  
**OCT**



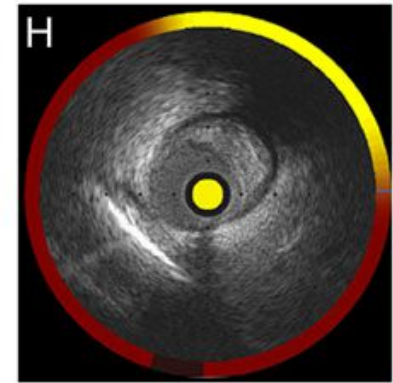
Macrophages



Microvessels



Plaque rupture



Lipid-rich plaque



**OCT**

**NIRS**

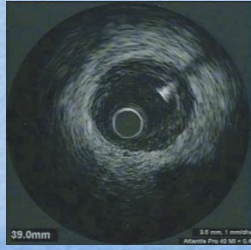
# Técnicas de imagen. Comparación

	IVUS	RF-IVUS	NIRS	OCT
General characteristics				
Energy source	Ultrasound	Ultrasound	Near-Infrared light	Infrared light
Pullback speed (mm/s)	0.5–1.0	0.5–1.0	0.5 <sup>[L]</sup> <sub>[SEP]</sub> –1–2 <sup>[L]</sup> <sub>[SEP]</sub> n/a	10–40 <sup>[L]</sup> <sub>[SEP]</sub> –1–
Penetration (mm)	0.8–10	8–10	No	3 <sup>[L]</sup> <sub>[SEP]</sub> –10
Spatial resolution (µm)	80–120	80–120		Yes
Requirement for blood clearance	No	No	Yes	Yes
Real-time outcome	Yes	No		
Assessment of native plaque				
Atheroma volume	Yes	Yes	No	No
Cap thickness	No	No	No	Yes
Arterial remodelling	Yes	Yes	No	No
Calcification	Good	Good	-	Modest
Lipid pool/necrotic core	-	Good	Good	Good
Imaging of non-superficial lipid-core plaque	-	Yes	No	No
Macrophage accumulation	No	No	No	Yes
Neovessels	-	-	-	Modest
Assessment of luminal integrity	Modest	Modest	-	Good
Stent/scaffold imaging				
PCI guidance	Yes	-	-	Yes
In-stent neoatherosclerosis	Poor	Modest	-	Good
Underexpansion	Yes	n/a	No	Yes
Malapposition	Yes	n/a	No	Yes
Strut uncoverage	No	No	No	Yes



	FD-OCT	IVUS
Ventajas	<ul style="list-style-type: none"> <li>✓ Alta resolución</li> <li>✓ Mejor identificación de placas lipídicas</li> <li>✓ Medición cápsula fibrosa</li> <li>✓ Placas “rotas” y trombo</li> <li>✓ Velocidad de retirada muy rápida</li> <li>✓ Menor interferencia con calcio y stents</li> <li>✓ Recubrimiento neointimal</li> </ul>	<ul style="list-style-type: none"> <li>✓ Mayor profundidad</li> <li>✓ Carga de placa</li> <li>✓ Remodelado positivo</li>   <li>✓ No precisa lavado de la arteria</li>   <li>✓ Evidencia científica</li> </ul>
Desventajas	<ul style="list-style-type: none"> <li>✓ Menor penetración, peor definición de placas grandes, remodelado positivo.</li> <li>✓ Necesidad de lavado de la arteria</li> </ul>	<ul style="list-style-type: none"> <li>✓ Menor resolución</li> <li>✓ Peor identificación lípidos, rotura de placa, trombo.</li> <li>✓ Retirada lenta</li> </ul>

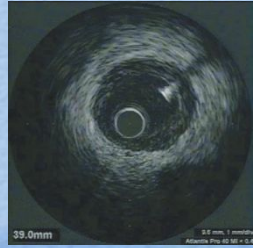
# Utilidad de IVUS



- Significación de lesiones
  - Lesiones intermedias
  - Lesiones tronco
  - Lesiones ostiales
  - Bifurcaciones
  - Imágenes ambiguas
- Placa vulnerable
- Regresión de placa
- Predicción de eventos en placas no responsables
- Guía del intervencionismo
- Valoración de stent: reestenosis , trombosis



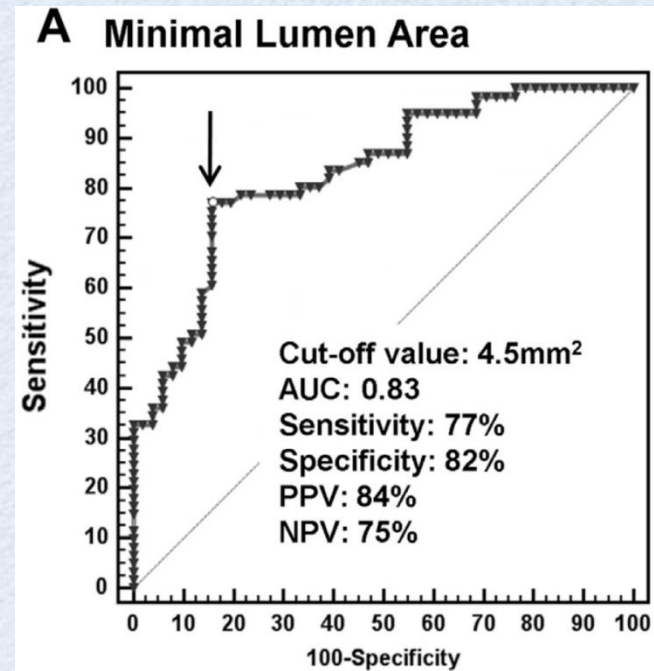
# Valoración de lesiones



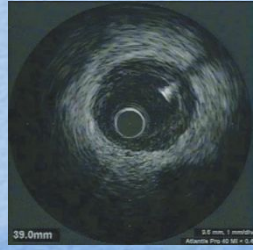
## IVUS-MLA Predicts LM FFR<0.80

Pure 112 LM lesion of DS 30-80%, exclude distal stream disease

**MLA 4.5mm<sup>2</sup>**



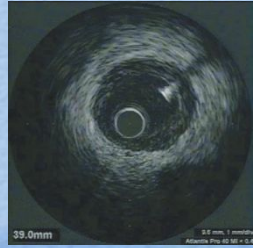
# Lesiones intermedias



- Un ALM  $> 4 \text{ mm}^2$  en una lesión en un vaso proximal (no TCI), nos permite con seguridad y baja tasa de eventos, no realizar intervencionismo sobre ella.
- Sb. es preferible la valoración funcional (FFR) st. en pacientes estables y en lesiones no culpables
- El IVUS puede ser preferible en:
  - Lesiones irregulares (ulceradas, disecadas...)
  - Defectos de contrastación (nodulares, lineales...)
  - Posibles artefactos (ostium tronco, ostium CD...)
  - No bien visualizables (tri-bifurcaciones, superposiciones de ramas,...)



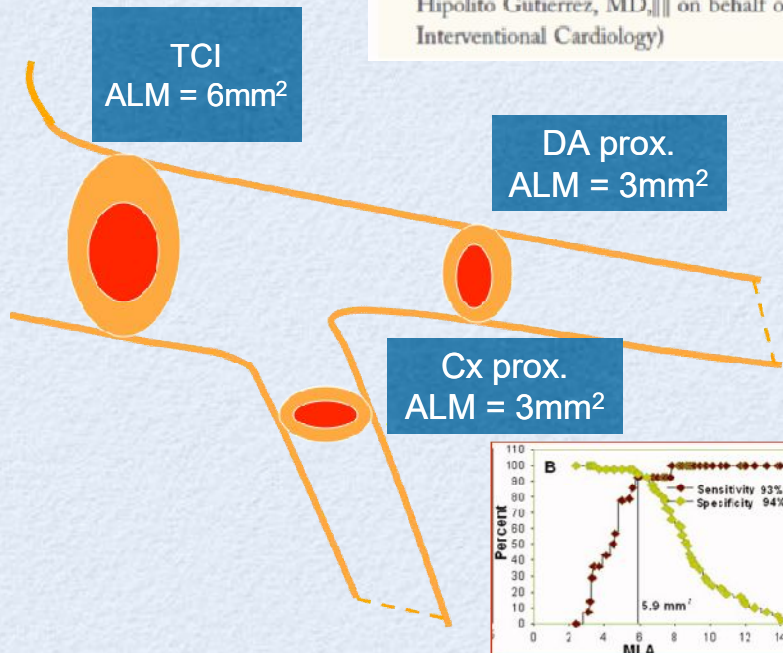
# Lesiones de tronco



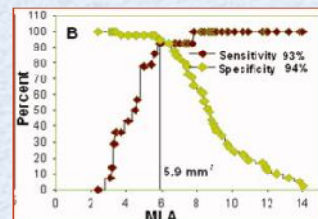
## Prospective Application of Predefined Intravascular Ultrasound Criteria for Assessment of Intermediate Left Main Coronary Artery Lesions

Results From the Multicenter LITRO Study

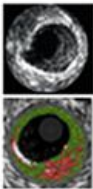
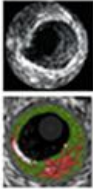
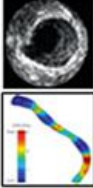

Jose M. de la Torre Hernandez, MD, PhD,\* Felipe Hernández Hernandez, MD,† Fernando Alfonso, MD, PhD,‡ Jose R. Rumoroso, MD, PhD,|| Ramon Lopez-Palop, MD, PhD,§ Mario Sadaba, MD,‡ Pilar Jimenez Carrillo, MD, PhD,|| Juan Rondon, MD, PhD,¶ Iñigo Lozano, MD, PhD,¶ J. M. Ruiz-Nodar, MD, PhD,‡ Jose A. Baz, MD,\*\* Eduard Fernandez Nofrerias, MD,†† Fernando Pajin, MD,‡‡ Tamara Garcia Camarero, MD,\* Hipolito Gutierrez, MD,||| on behalf of the Litro Study Group (spanish Working Group on Interventional Cardiology)



Validación prospectiva de **ALM = 6 mm<sup>2</sup>** como corte para revascularización del TCI en nuestra población  
354 pacs en 22 centros

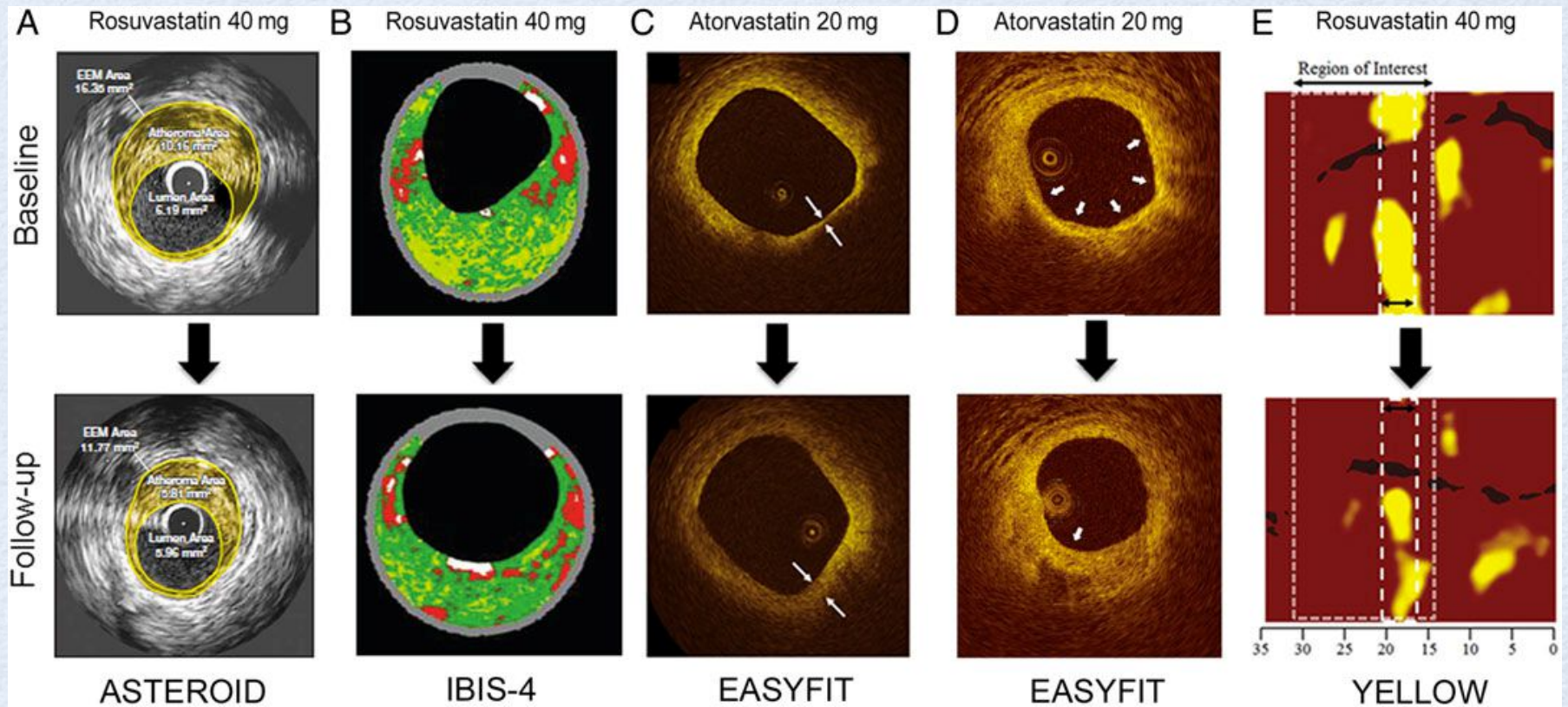


# Predicción de eventos: placa vulnerable

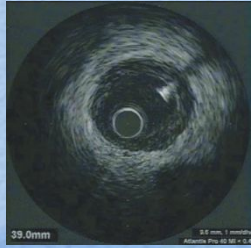
Study	Modality	Lesion characteristic(s)	Clinical endpoint	Positive predictive value	Negative predictive value
PROSPECT <i>n</i> =697	 IVUS & IVUS-VH	PB $\geq$ 70% & MLA <4mm <sup>2</sup> & IVUS-VH TCHA	MACE	18%	98%
ATHEROREMO IVUS <i>n</i> =581	 IVUS & IVUS-VH	PB $\geq$ 70% & MLA <4mm <sup>2</sup> & IVUS-VH TCHA	MACE	23%	93%
PREDICTION <i>n</i> =506	 IVUS & ESS	PB $\geq$ 58% & Low ESS <1.0 Pa	PCI	41%	92%
ATHEROREMO NIRS <i>n</i> =203	 NIRS	LCBI <sub>4mm</sub> >43	MACE	12%	99%



# Regresión de placa



# ICP



## 1.-Preintervención

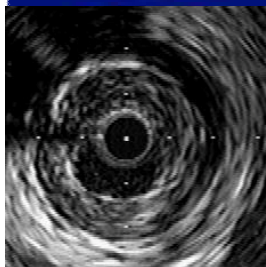
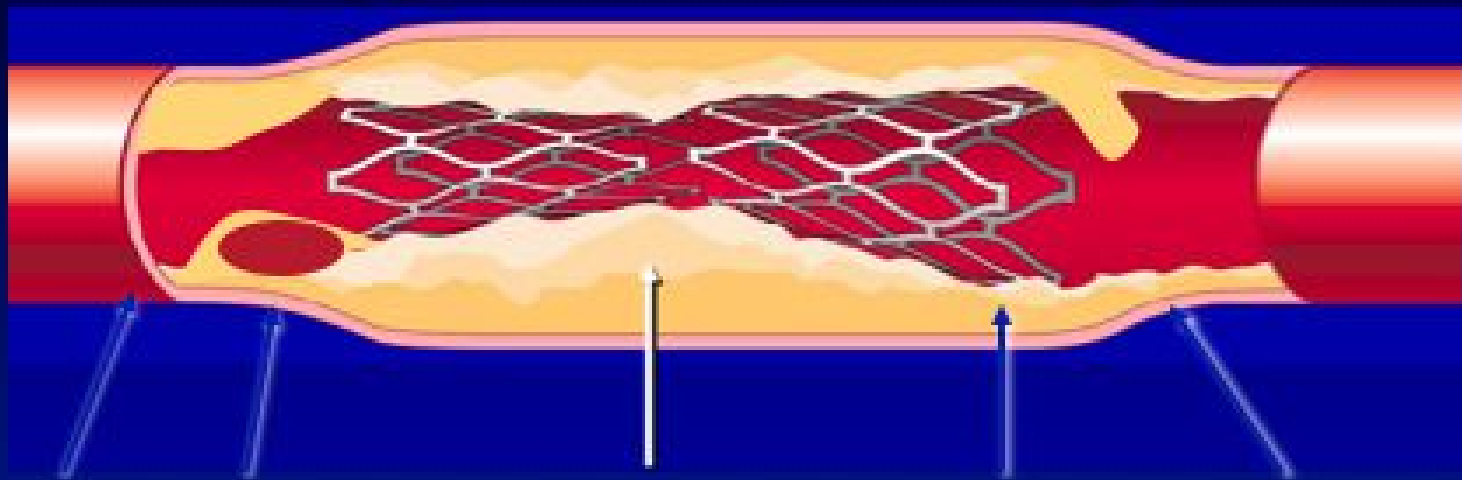
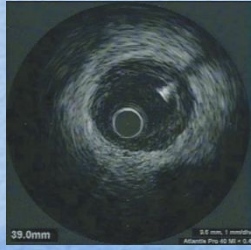
- Medida precisa del vaso y la luz para maximizar el tamaño del stent
- Identificar las zonas de referencia proximal y distal ideales para optimizar la longitud del stent
- Determinar cuando es necesario RTB previo

## 2.-Postintervención

- Maximizar CSA en relación a la referencia
- Asegurar cobertura completa de la lesión
- Reconocer/diagnosticar/tratar complicaciones - imágenes dudosas –resultados subóptimos
- Subgrupos de lesiones específicos (LM, lesiones largas, ostiales, alto riesgo, procedimientos complejos etc )



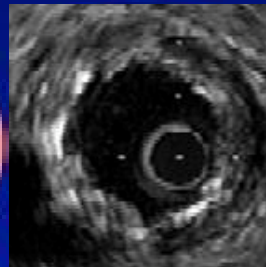
# Post-ICP: problemas



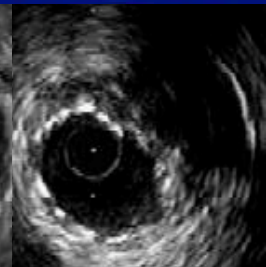
Enf.  
bordes



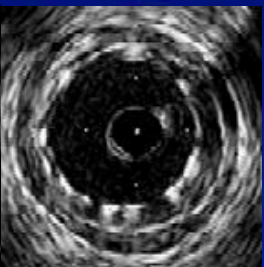
Hematoma



Rotura stent  
Prolapso placa



Subexpansion

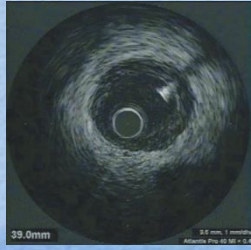


Aposicion  
Incompleta



Diseccion  
en margenes

# ICP sin contraste



## Imaging- and physiology-guided percutaneous coronary intervention without contrast administration in advanced renal failure: a feasibility, safety, and outcome study

Ziad A. Ali, Keyvan Karimi Galougahi, Tamim Nazif, Akiko Maehara, Mark A. Hardy, David J. Cohen, Lloyd E. Ratner, Michael B. Collins, Jeffrey W. Moses, Ajay J. Kirtane, Gregg W. Stone, Dimitri Karpaliotis, Martin B. Leon

**31 patients with advanced CKD** [creatinine = 4.2 mg/dL (IQR) 3.1-4.8, GFR =  $16 \pm 8$  mL/min/1.73 m<sup>2</sup>] who had clinical indication for PCI based on a prior minimal contrast coronary angiogram.

**Zero contrast PCI** was performed at least 1 week after diagnostic angiography using IVUS guidance, with pre- and post-PCI FFR to confirm improvement.

**100% successful** PCI, no events and **preservation of renal function** without the need for RRT within a follow-up time of 79 days .

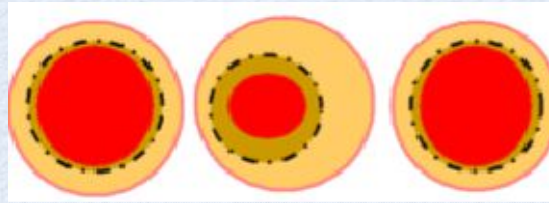
for RRT within a follow-up time of 79 days .

**100% successful** PCI, no events and **preservation of renal function** without the need

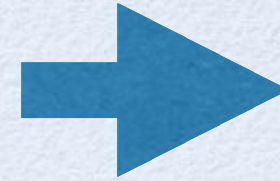
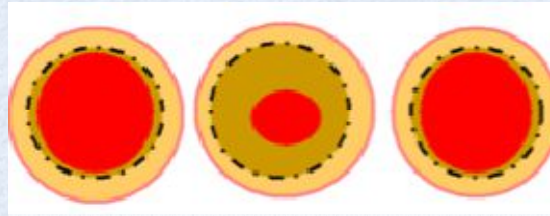


# Valoración del stent a largo plazo

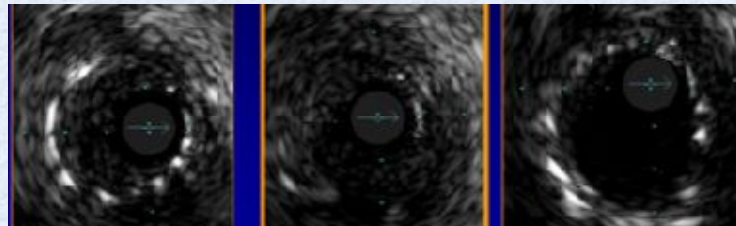
Infraexpansión



Proliferación intimal



Fractura de stent



REESTENOSIS

# Intracoronary Imaging

## Clinical use in interventional practice (Decision-making and procedural guidance)

### Lesion assessment (inconclusive angiography)

Evaluation of angiographically intermediate left main lesions

IVUS<sup>60,64,67</sup>

- Verification of the culprit lesion of an ACS
- Identification of plaque rupture / erosion / thrombus

OCT<sup>17,55,56</sup>, IVUS<sup>60</sup>

### Detecting mechanisms of stent restenosis / thrombosis

- Underexpansion
- Malapposition
- Strut uncoverage
- In-stent neoatherosclerosis
- Stent fracture
- Edge-related disease progression

OCT<sup>60,81,82,96,97</sup>, IVUS<sup>60,93</sup>

### Stenting-related imaging

#### PCI guidance

- Optimal sent length selection → assurance of complete lesion coverage
- Optimal stent size selection → prevention of stent under- or oversizing
- Determination of stenting technique (bifurcation lesions)

IVUS<sup>60,72-77</sup>, OCT<sup>60,83,85</sup>

#### PCI optimization

- Detection of underexpansion
- Detection of malapposition
- Detection of edge dissection
- Detection of geographical miss
- Detection of intra-stent mass

OCT<sup>60,85</sup>, IVUS<sup>60,74,77</sup>

## Imaging of native coronary atherosclerosis with potential for clinical utility

### Non-culprit / asymptomatic lesions

#### Global disease burden (Global approach)

- Measurement of atheroma volume
- Serial progression / regression
- Effect of anti-atherosclerotic medications on global disease burden

IVUS<sup>5,37-40</sup>

#### Focal plaque characterization (Local approach)

- “Vulnerable” plaque detection
- IVUS: attenuated plaque, remodeling<sup>6,24</sup>  
VH-IVUS: TCFA phenotype<sup>7,27-29</sup>  
OCT: Fibrous cap thickness, macrophages, microvessels<sup>11,20</sup>  
NIRS: Lipid core burden<sup>12,23,32</sup>  
Hybrid imaging, emerging modalities (μOCT, NIRF/NIRAF, IVPA, FLIm)<sup>101-112</sup>  
Shear stress measurement<sup>31,52-54</sup>

### Lesions planned for PCI

- Identification of “high-risk” lesion for PCI-related complications (distal embolization, thrombosis)

VH-IVUS<sup>33</sup>, NIRS<sup>34</sup>

- Identification of plaque rupture vs. erosion in culprit lesions of acute coronary syndromes (prognostic implications)

OCT<sup>17,36</sup>



# Razones para la reducción del uso del IVUS

- **No good clinical data**
  - IVUS use is associated with a high rate of complications
  - Vocal anti-IVUS statements by some prominent interventionalists
  - Live demonstration courses and public posturing vs actual practice
  - Image interpretation – not understanding the image and how to use the information
  - Too much information – don't know what is/is not important
  - Lack of consensus among experts
  - Guidelines do not give Class I indication
  - Inertia – especially among senior interventionalists
  - Lack of education – especially for junior interventionalists
  - Poor image quality or inconsistency – often requires expert interpretation and inhibits confidence in new users
  - Intimidation by experts
  - No new advances in IVUS despite major investments
- **OCT is better**
  - Ambivalence among stent companies
  - Rapidly changing PCI landscape
  - Procedural inefficiency
  - Resistance from staff
  - Past history and experience
  - Poor catheter performance and recalls
  - Chronic, nagging hardware problems
  - Poor marketing strategies both domestically and internationally – no “magic bullet”; and every country is different
  - Cost
  - Competition – when the real competition is angiography and not other intravascular imaging companies and technologies
  - No open interface
  - Mature technology

# Evidencia científica



# Meta-analisis de Trials IVUS vs Angiografia en implantacion de BMS (n=2.193 pts)

**El uso de IVUS se asocio a menos:**

– **Reestenosis Angiografica**

**(22.2% vs. 28.9%; p=0.02)**

– **Revascularizacion Repetida**

**(12.6% vs. 18.4%; p=0.004)**

– **MACE**

**(19.1% vs. 23.1%; p=0.03)**

	Angio Better	IVUS Better
Choi et al (Am Heart J 2001)		X
CENIC (JACC 2002)		X
CRUISE (Circulation 2000)		X
SIPS (Circulation 2000)		X
AVID (Circ. Interv. In press)		X
Gaster et al (Heart 2003)		X
RESIST (JACC 1998)		X
TULIP (Circulation 2003)		X
BEST (Circulation 2003)		X
OPTICUS (Circulation 2001)	X	
PRESTO ( Am Heart J 2004)	X	
DIPOL ( Am Heart J 2007)		X

**Original Investigation**

# **Effect of Intravascular Ultrasound-Guided vs Angiography-Guided Everolimus-Eluting Stent Implantation The IVUS-XPL Randomized Clinical Trial**

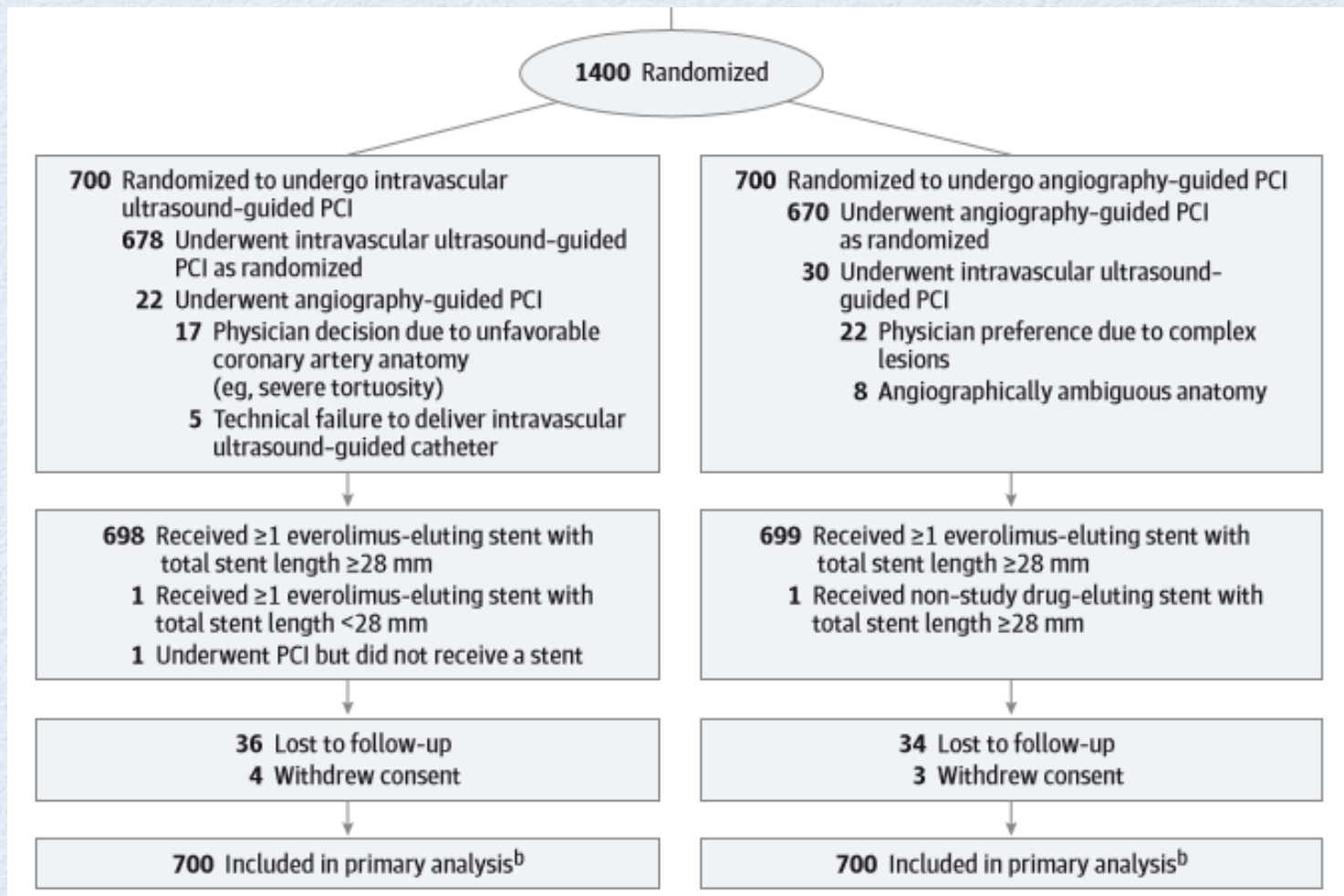
Sung-Jin Hong, MD; Byeong-Keuk Kim, MD; Dong-Ho Shin, MD, MPH; Chung-Mo Nam, PhD; Jung-Sun Kim, MD; Young-Guk Ko, MD; Donghoon Choi, MD; Tae-Soo Kang, MD; Woong-Chol Kang, MD; Ae-Young Her, MD; Yonghoon Kim, MD; Seung-Ho Hur, MD; Bum-Kee Hong, MD; Hyuckmoon Kwon, MD; Yangsoo Jang, MD; Myeong-Ki Hong, MD, PhD; for the IVUS-XPL Investigators

Implantación de EES en lesiones coronarias largas  
(longitud del stent > 28 mm) basado en estimación angiográfica

JAMA 2015 ;314:2155-63

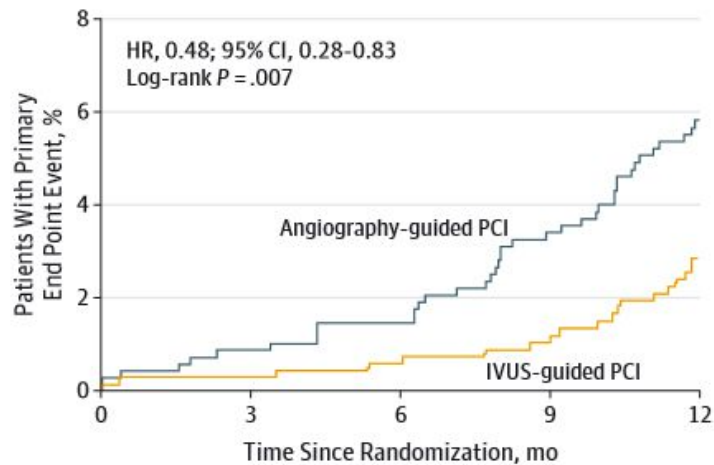


# IVUS - XPL



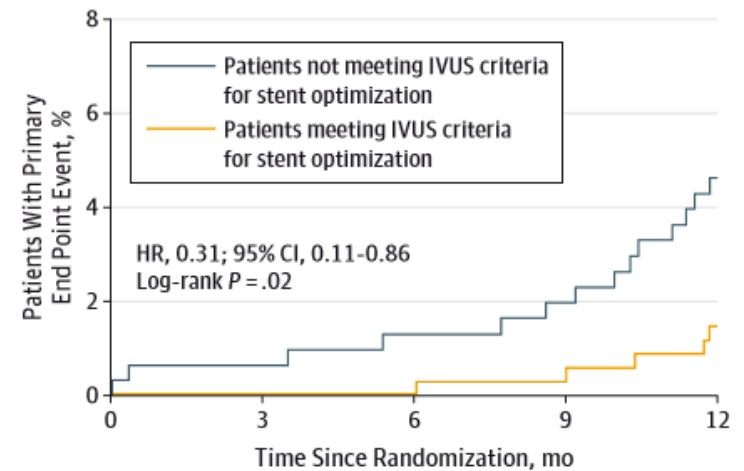
# Primary end-point: Cardiac death, TL-MI, TLR

**A** All patients



No. at risk		0	3	6	9	12
PCI						
Angiography-guided	700	673	660	643	624	
IVUS-guided	700	671	665	654	641	

**B** Patients in IVUS-guided PCI group who underwent IVUS-guided stent implantation<sup>a</sup>



No. at risk		0	3	6	9	12
IVUS criteria						
Not meeting	315	299	297	394	285	
Meeting	363	362	345	338	334	

**Apellido IVUS para optimización del stent:**

MLA stent > Distal area luminal

**Conseguido 54%**



	IVUS-Guided PCI (n = 700) <sup>a</sup>	Angiography-Guided PCI (n = 700) <sup>a</sup>	P Value <sup>c</sup>
<b>Primary End Point</b>			
Major adverse cardiac event <sup>d</sup>	19 (2.9)	39 (5.8)	.007
<b>Secondary End Point</b>			
Cardiac death	3 (0.4)	5 (0.7)	.48
Target lesion-related myocardial infarction	0	1 (0.1)	.32
Ischemia-driven target lesion revascularization	17 (2.5)	33 (5.0)	.02
Definite or probable stent thrombosis	2 (0.3)	2 (0.3)	>.99
Acute	1 (0.1)	1 (0.1)	
Subacute	1 (0.1)	0	
Late	0	1 (0.1)	

# IVUS - XPL

El uso de IVUS durante el procedimiento de ICP con DES en enfermedad difusa reduce la necesidad de nuevas revascularizaciones



# Meta-Análisis de estudios de IVUS vs Angiografía en implantación de DES (n=19.619)

Comparado con angiografía, el uso de IVUS en el implante de DES se asocio a menos:

## Muerte

(HR: 0.58, 95% CI: 0.47-0.71,  $p < 0.001$ )

## MACE

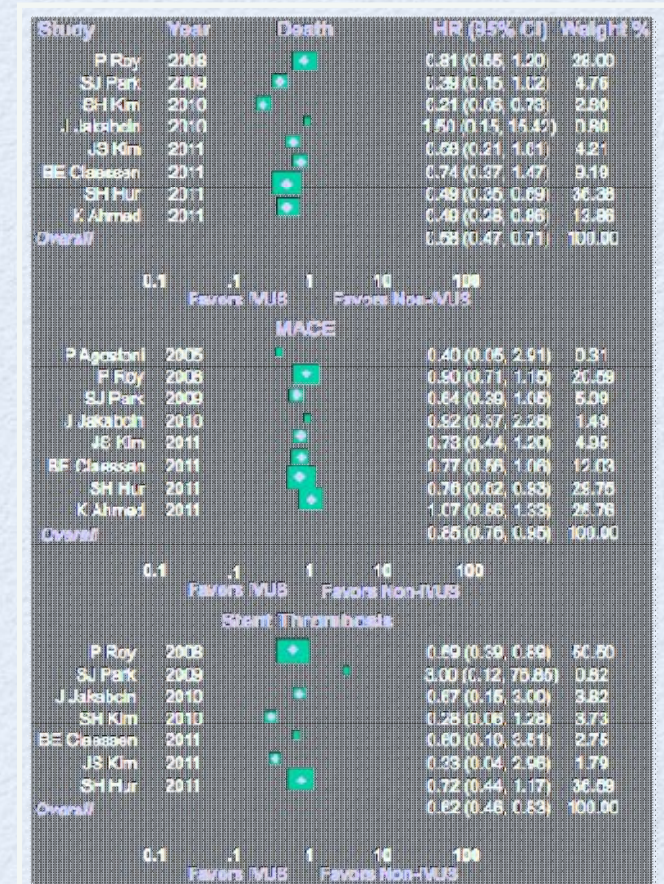
(HR: 0.85, 95% CI: 0.76-0.95,  $p = 0.005$ )

## Trombosis de Stent

(HR: 0.62, 95% CI: 0.46-0.83,  $p = 0.002$ )

## No efecto en IM

## No efecto en TLR



# Outcomes With Intravascular Ultrasound-Guided Stent Implantation A Meta-Analysis of Randomized Trials in the Era of Drug-Eluting Stents

Islam Y. Elgendy, MD\*, Ahmed N. Mahmoud, MD\*, Akram Y. Elgendy, MD and  
Anthony A. Bavry, MD, MPH

Seven trials with 3192 patients  
Mean lesion length 32 mm

**Con una media de seguimiento de 15 meses  
el uso rutinario del IVUS para guiar la ICP se asocia:**

Reducción del riesgo de MACE

(6.5% versus 10.3%; OR 0.60; 0.46–0.77;  $P < 0.0001$ )

Reducción de la isquemia derivada del TLR

(4.1% versus 6.6%; OR 0.60; 0.43–0.84;  $P = 0.003$ ).

Menor mortalidad cardiovascular

(0.5% versus 1.2%; OR 0.46; 0.21–1.00;  $P = 0.05$ )

Menor trombosis del stent

(0.6% versus 1.3%; OR 0.49; 0.24–0.99;  $P = 0.04$ )

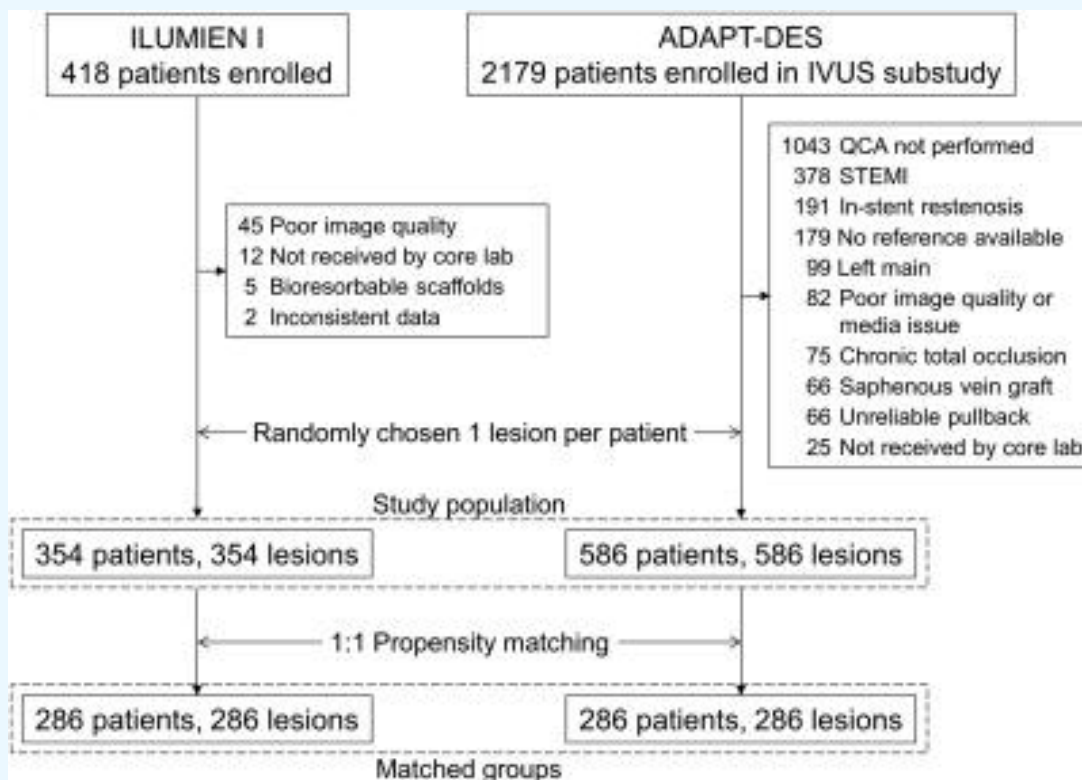


El uso de IVUS durante el procedimiento de ICP con DES, especialmente en enfermedad difusa, reduce la necesidad de nueva revascularización y probablemente también de trombosis y mortalidad cardiaca

# Comparison of Stent Expansion Guided by Optical Coherence Tomography Versus Intravascular Ultrasound



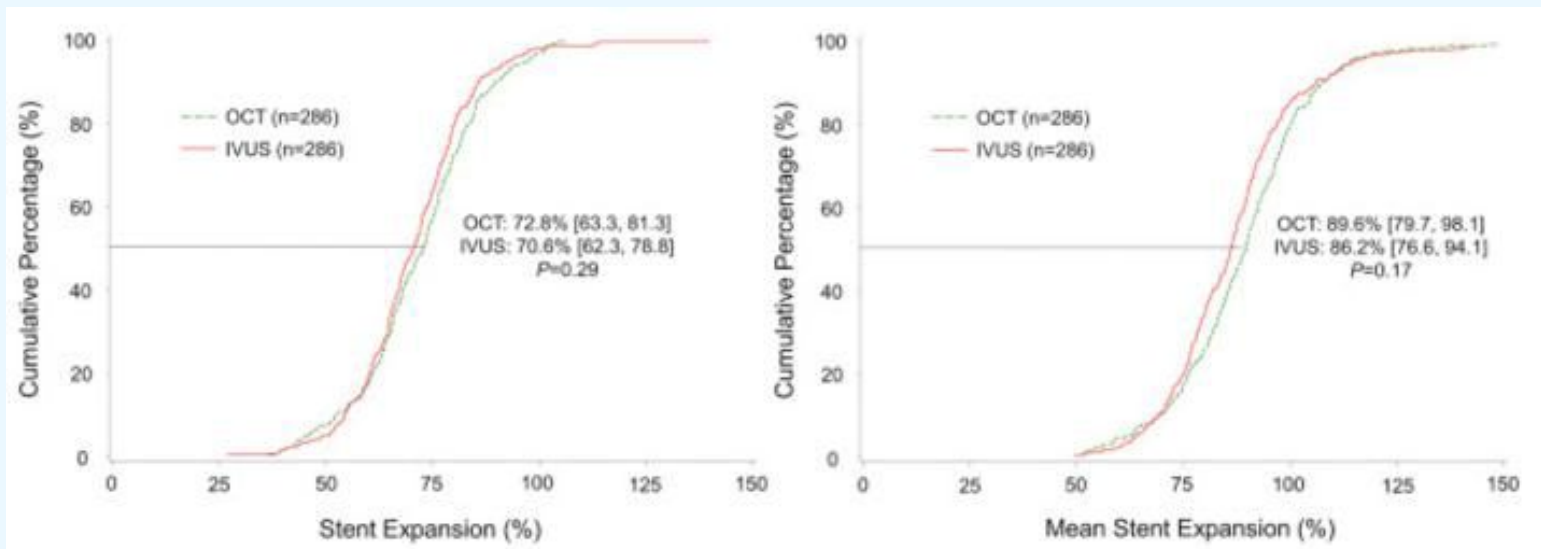
The ILUMIEN II Study (Observational Study of Optical Coherence Tomography [OCT] in Patients Undergoing Fractional Flow Reserve [FFR] and Percutaneous Coronary Intervention)



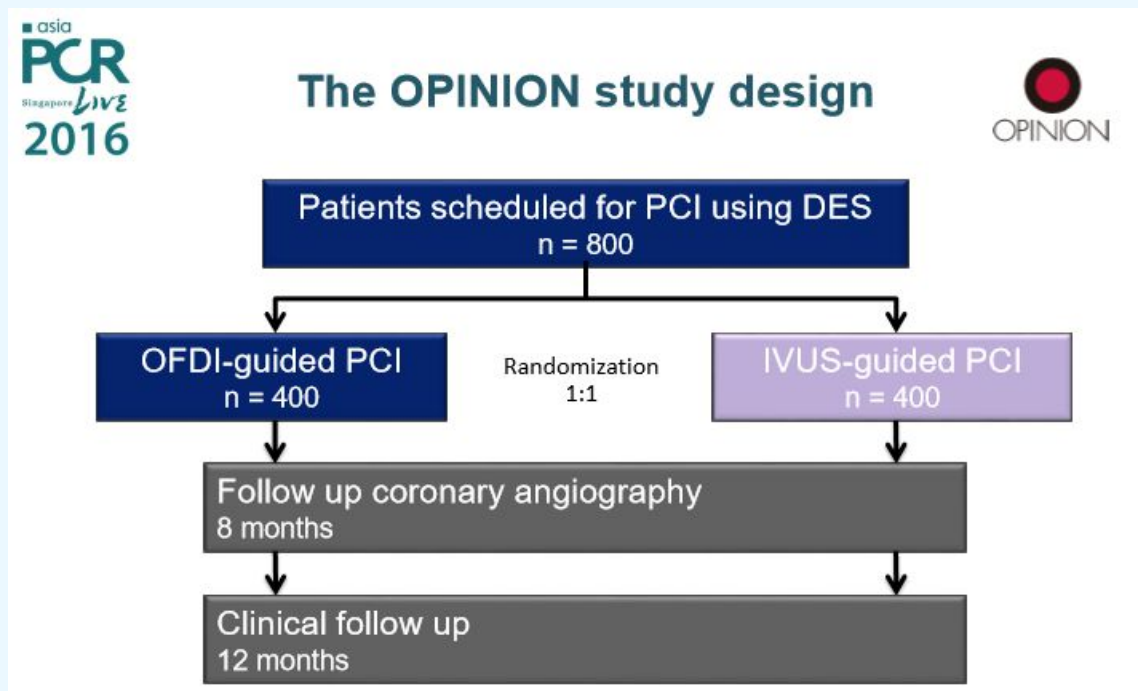


No se observan diferencias significativas en el grado de expansión de los stents obtenido mediante uso de IVUS u OCT

OCT detecta mas hallazgos de grado menor , pero sin diferencia con el IVUS para los de grado mayor.



# Optical frequency domain imaging vs. IVUS in PCI: the OPINION trial - one-year primary endpoint results





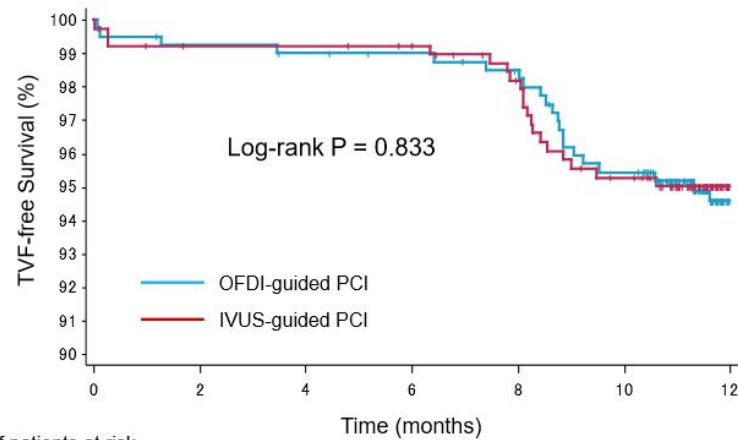
# El impacto clínico del uso de IVUS y OCT en los procedimientos de ICP con DES resulta similar

euro  
PCR

## Target vessel failure (TVF)-free survival curves

OPINION

TVF = composite of cardiac death, target vessel-related MI and clinically-driven TVR



No. of patients at risk

OFDI-guided PCI	401	396	394	392	387	374	265
IVUS-guided PCI	390	384	384	381	373	360	285

# ¿Que dicen las guías?

## ESC guidelines 2014

Recommendations	Class	Level
<b>IVUS</b> in selected patients to optimize stent implantation.	<b>IIa</b>	<b>B</b>
<b>OCT</b> in selected patients to optimize stent implantation.	<b>IIb</b>	<b>C</b>

*Eur Heart J. 2014;35:2541-2619*



# Conclusiones

- A pesar de la reducción en su utilización, existe una gran evidencia científica que avala el uso de IVUS:
  - En la optimización de la implantación de stent (BMS o DES)
  - Predicción de efectos adversos
  - Su uso en la ICP comparado con la angiografía aislada
  - La valoración de la reestenosis/trombosis del stent y la elección del mejor tratamiento.

Gracias por su atención



¿Dudas, preguntas,  
sugerencias?

¿Coffee, tea,...?

