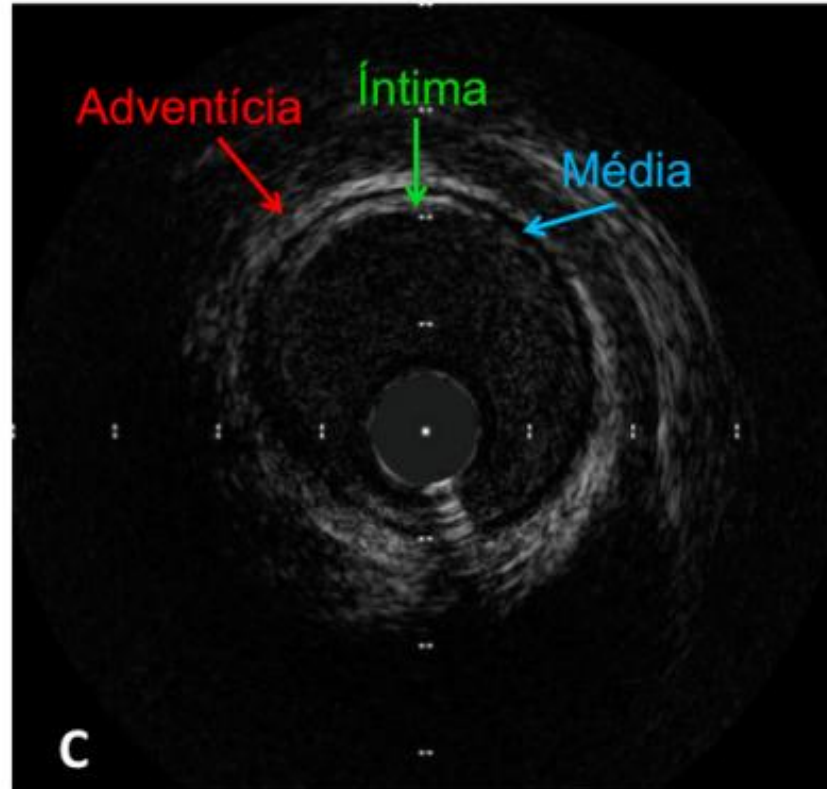


Ultrassom Intracoronário



Renato Sanchez, MD

Qual é o equipamento necessário?

- **Cateter e transdutor:** entre 2,6-3,5 F, compatível com um cateter guia 6F.
- **Dispositivo de recuo:** o transdutor pode ser avançado ou puxado manualmente.
- A velocidade do recuo automático varia entre 0,25-1,0 mm/s.
- **Console:** É composto por um hardware e software para reconstrução de imagens, dispositivos de gravação e um monitor.

Qual é a técnica de exame?

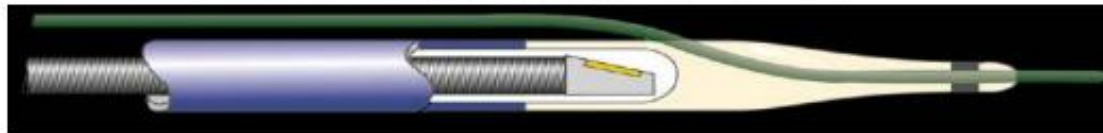
- Anticoagulação com heparina intravenosa (5000-10000 unidades), 100-300 μg de nitroglicerina intracoronária para dilatação máxima e prevenir espasmos.
- Fio-guia de 0,014 polegadas é colocado na artéria alvo.
- Em seguida, o cateter de USIC é colocado distal à área de interesse ou com segurança o mais distal possível.

TRANSDUTOR

Pizoelétrico (elétrico \leftrightarrow som)

- ❖ **MECÂNICO** - Único elemento, rotatório (1800 rpm), 360° .
(Atlantis® - BOSTON™ - 40 MHz & Revolution® - VOLCANO™ - 45 MHz)
Short Monorail system. Ø 2,5 – 3,6 F
- ❖ **ELETRÔNICO** - Estado Solido, 64 transdutores acionados em sequência
(Eagle-Eye - VOLCANO™)-20 MHz
Monorail system. Ø 3,6 F

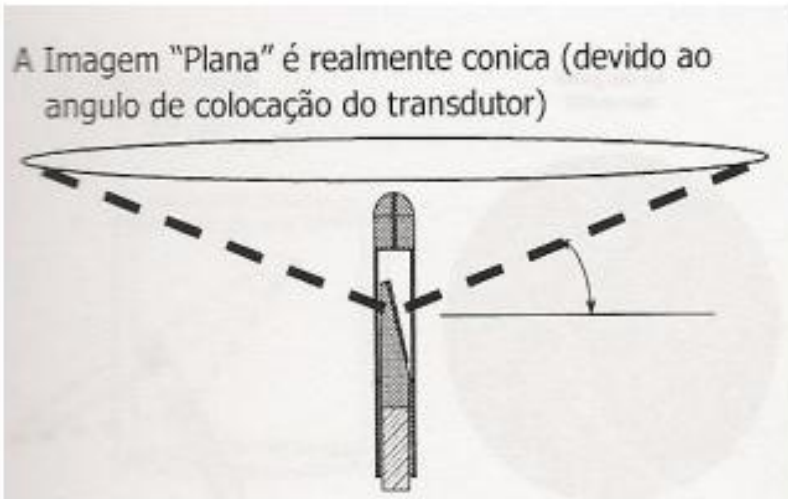
MECÂNICO - BOSTON & VOLCANO



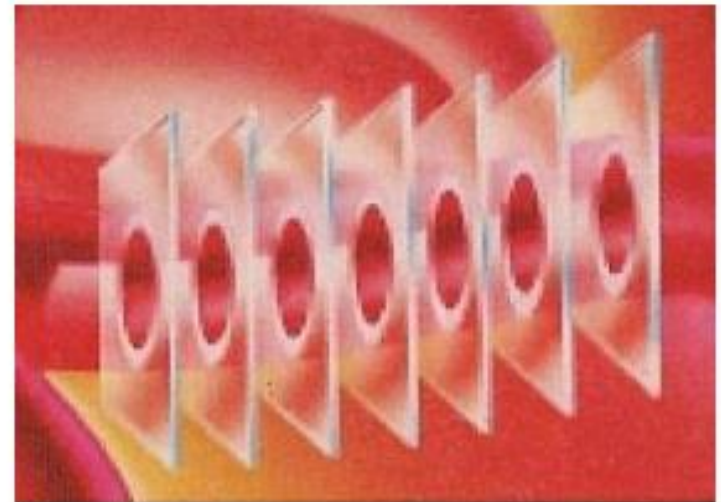
ELETRÔNICO - VOLCANO



Formação da Imagem

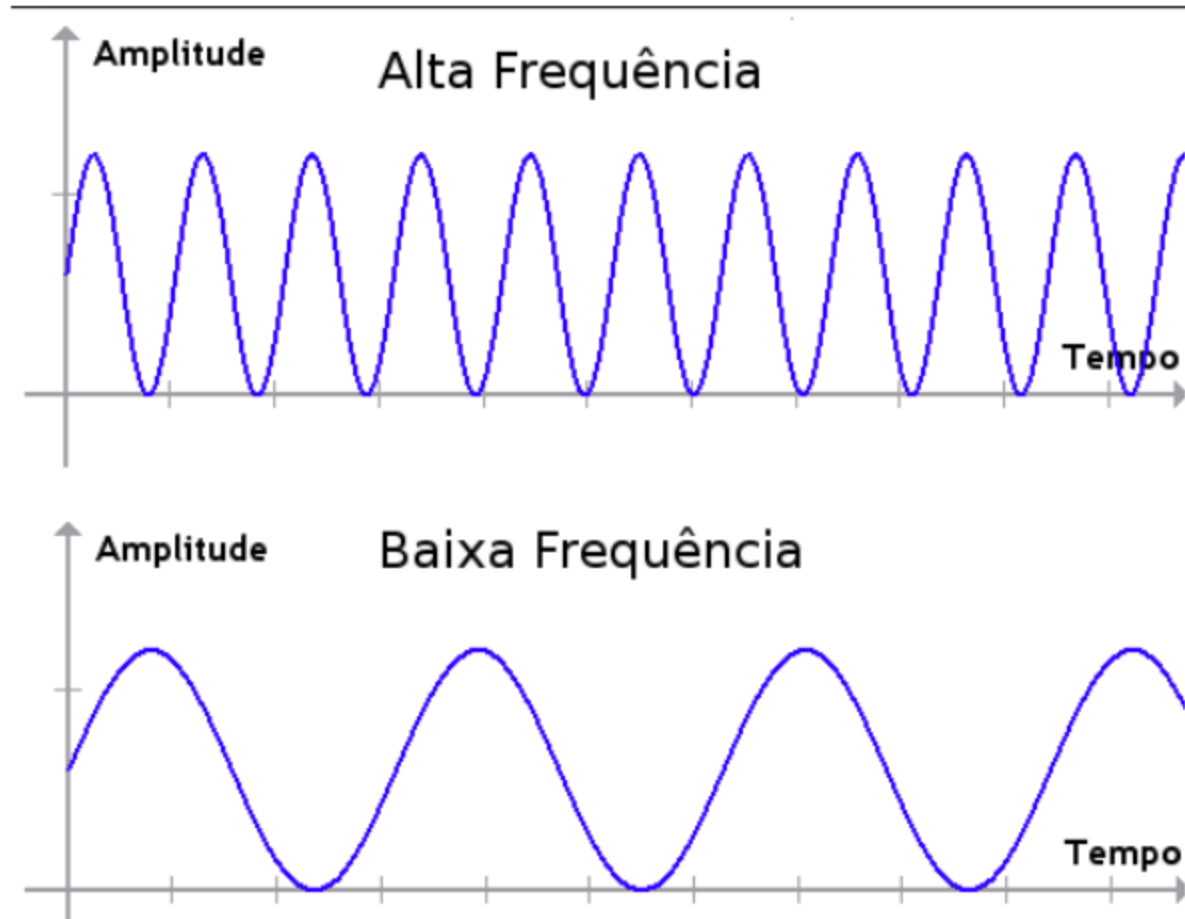


- **256 Pulsos / rotação**
1 Pulso/1,4 GRAU
- **Frame update rate = 30 / seg**



500 a 600 imagens / cm arteria

MAIOR Frequência / + Resolução / - Penetração
MENOR Frequência / - Resolução / + Penetração



< 100 -> Não identifica (FCF)
> 10 -> Não visualiza

| | |
|-------------------|-----------------------------|
| RESOLUÇÃO | 100μm |
| PENETRAÇÃO | 10 mm |

+ BRANCO / + REFLEXÃO

CARACTERÍSTICA ECOGRÁFICA

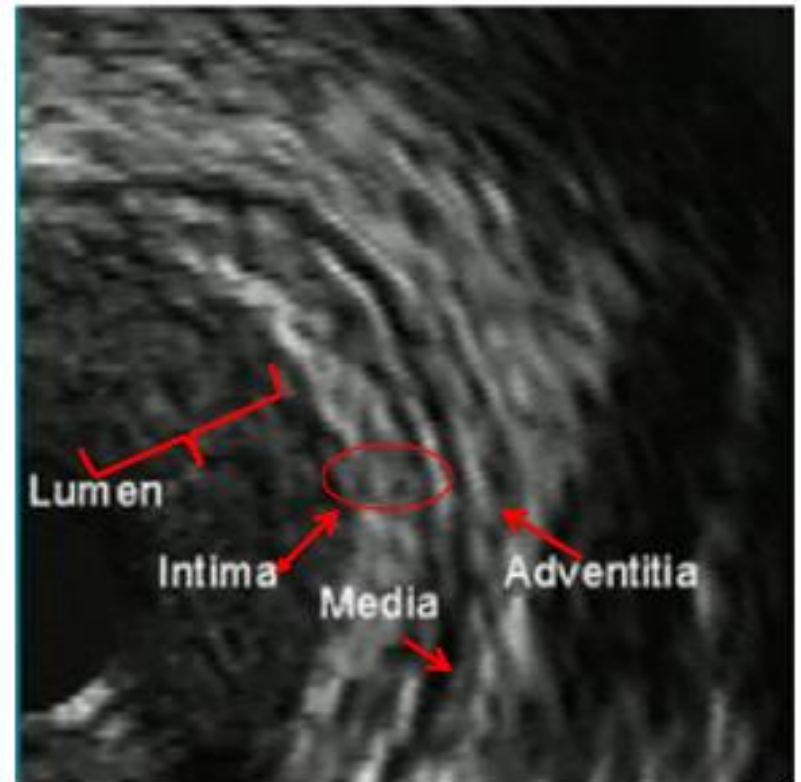
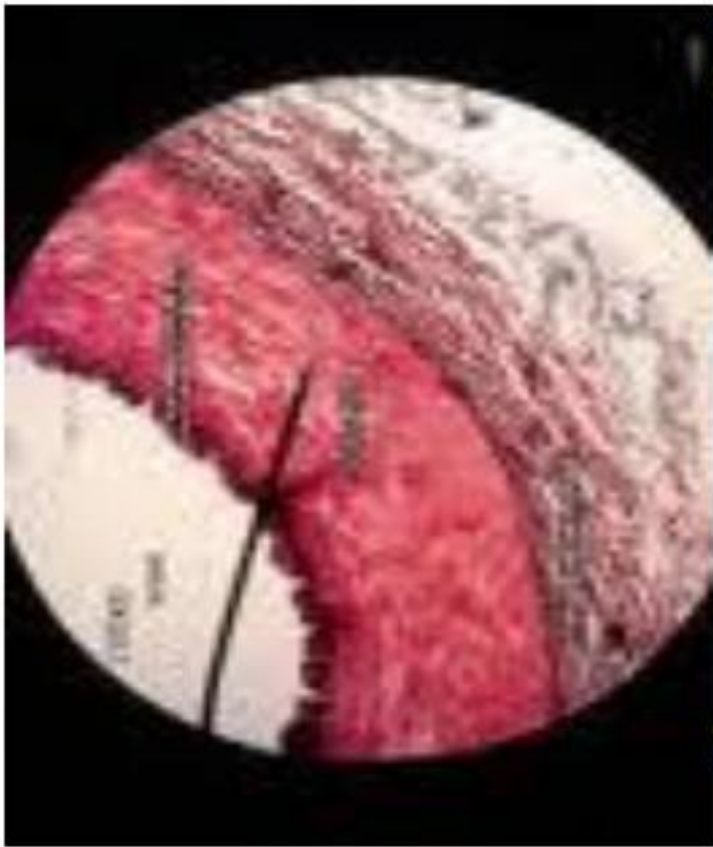
A intensidade do eco (reflexão) é que irá determinar a cor que a célula vai ter: branco para um eco forte, preto para um muito fraco.



COLÁGENO determina REFRINGÊNCIA

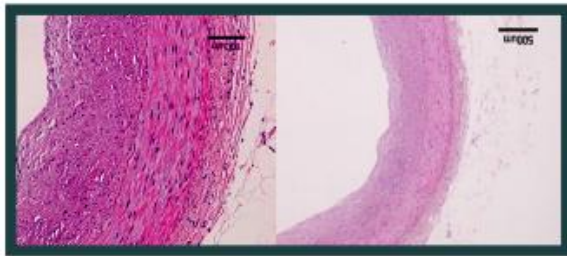
+ Colágeno / + Refringência / + Branca

- Colágeno / - Refringência / + Escuro (Ecolucente)

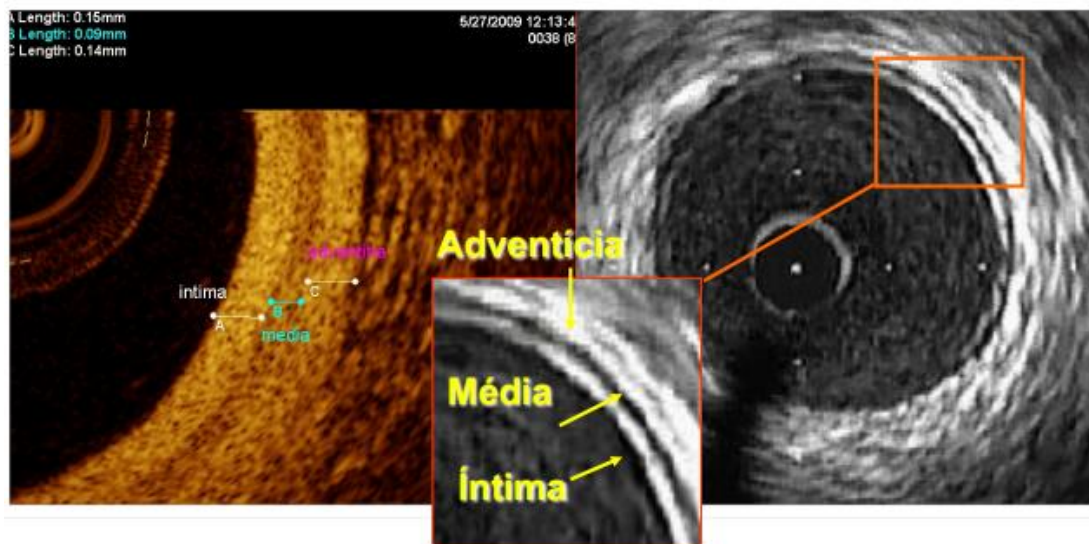


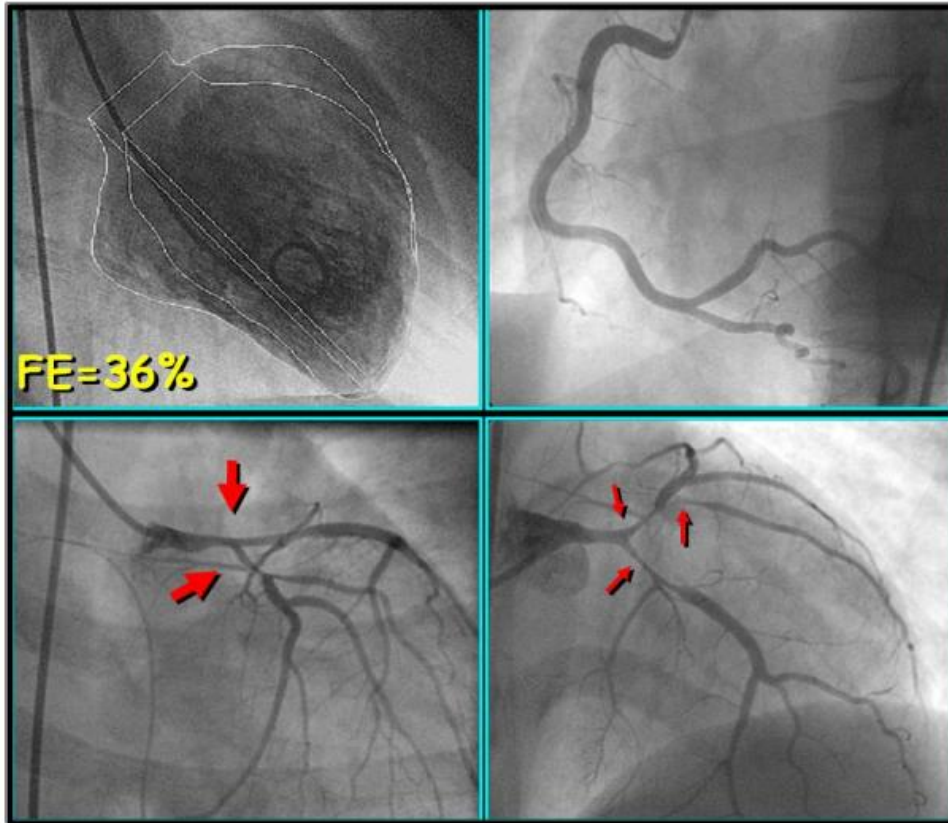
3 camadas: Adventícia/Média/Íntima + Idade / + Íntima

Morfologia da artéria coronária normal

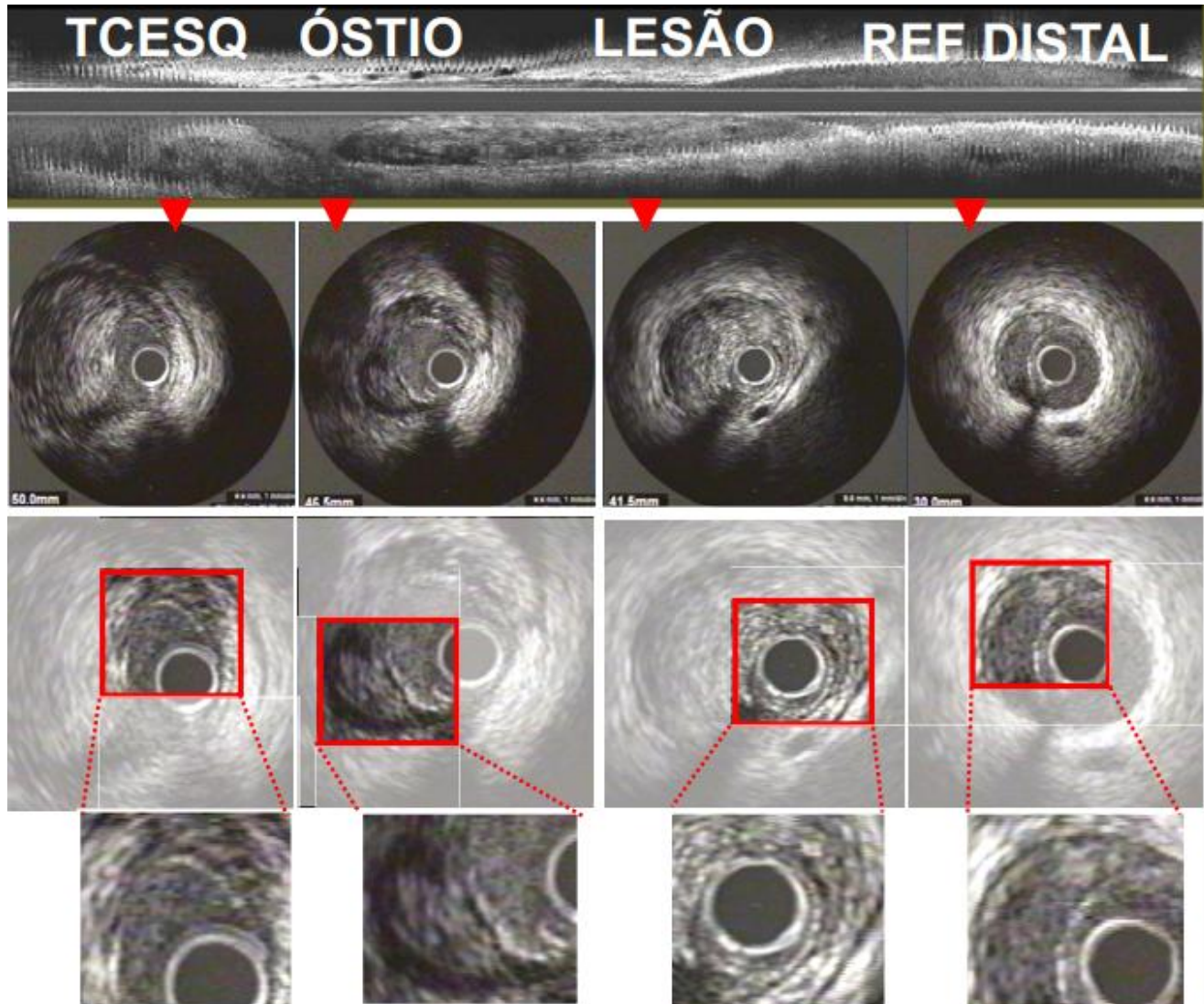


5 ANOS ÍNTIMA 60 μ m
30 ANOS ÍNTIMA 220 μ m
▲ 40 ANOS ÍNTIMA >250 μ m

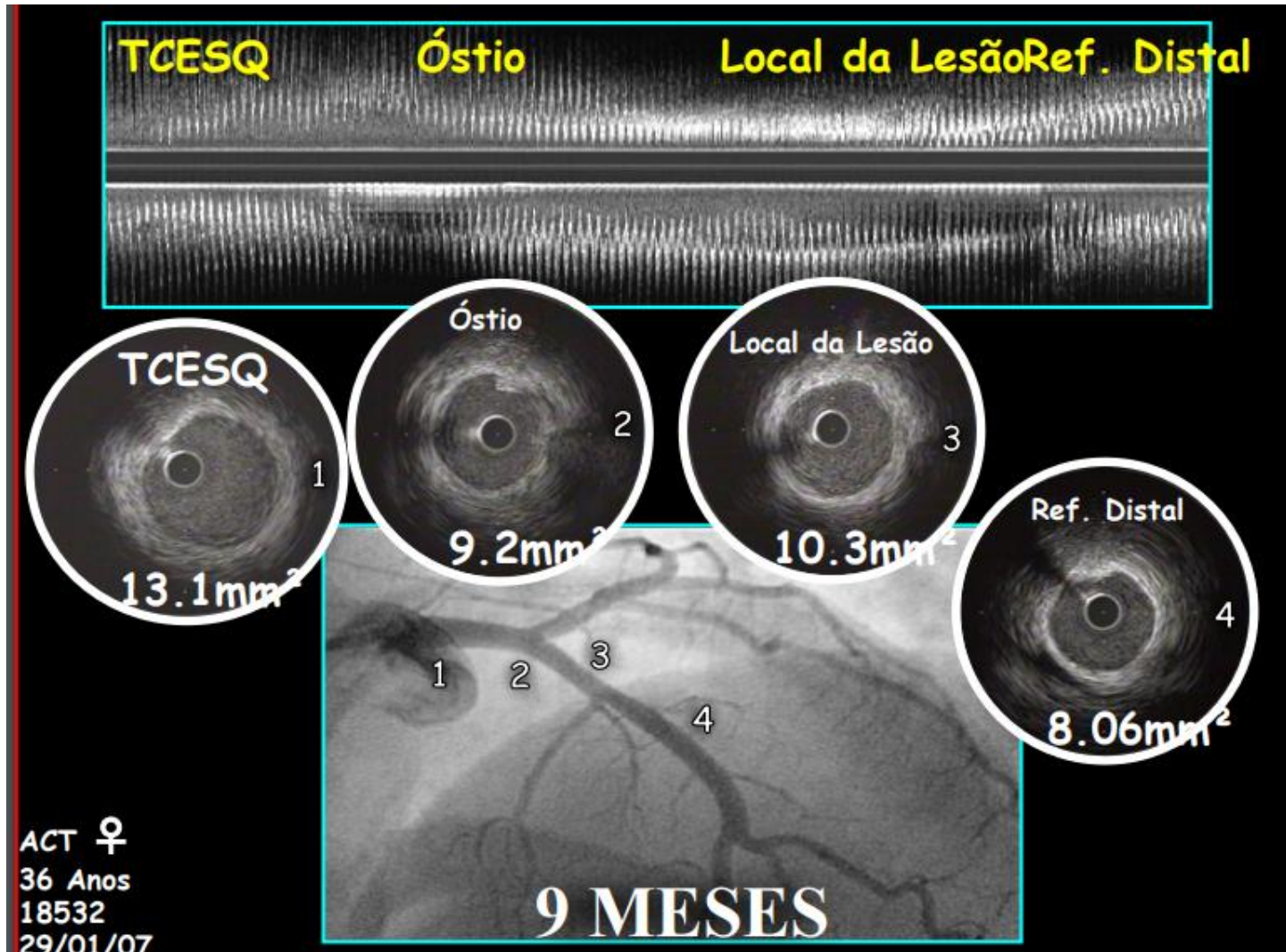




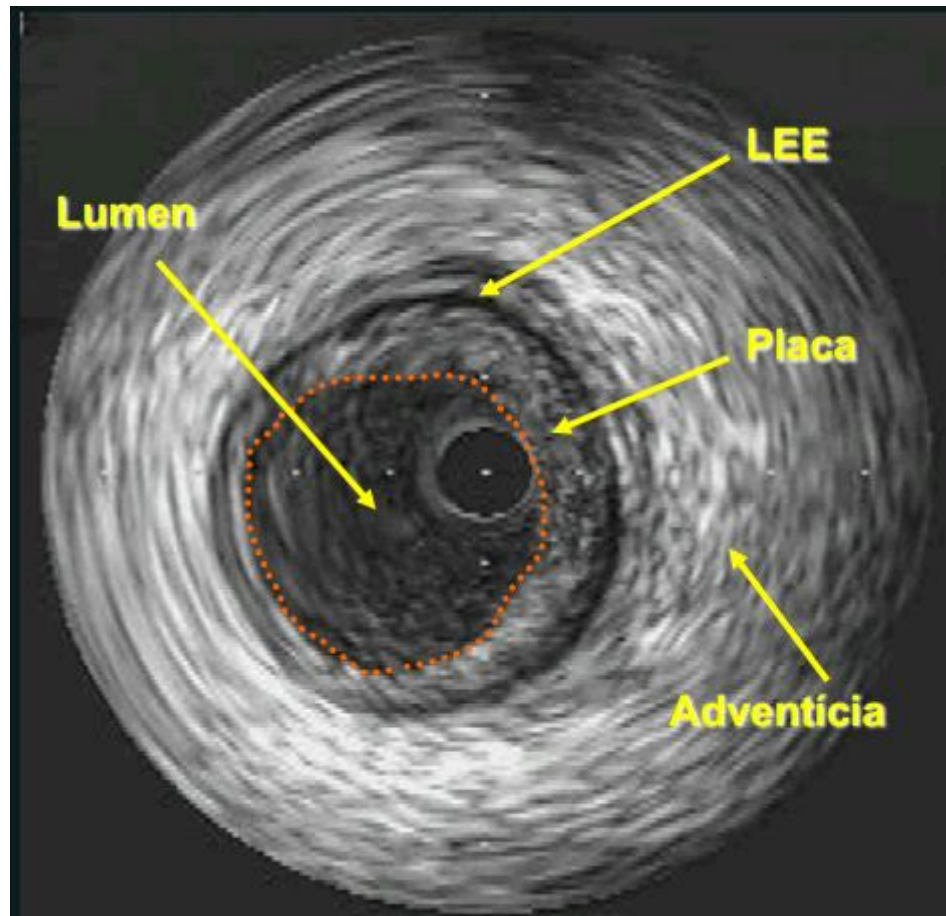
Avaliação QUALITATIVA (SUBJETIVA)



HEMATOMA localiza entre Média e Adventícia

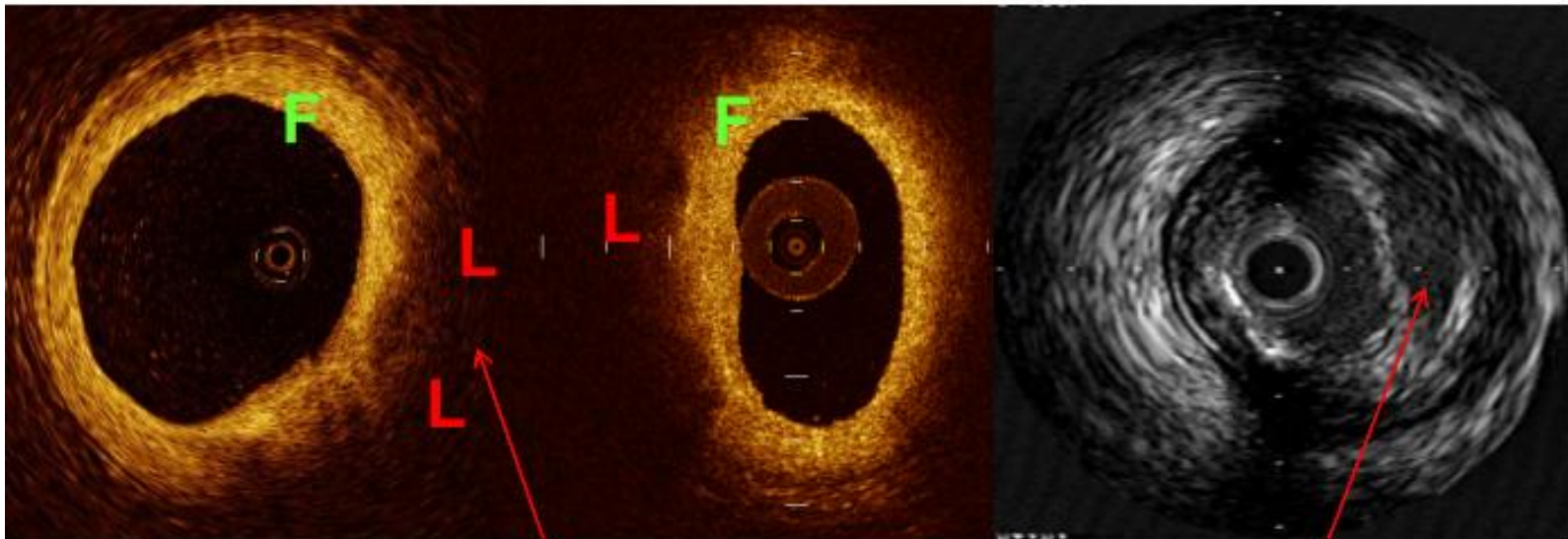


PLACA localiza entre Íntima e Média



Placa Lipídica e Fibrolipídica

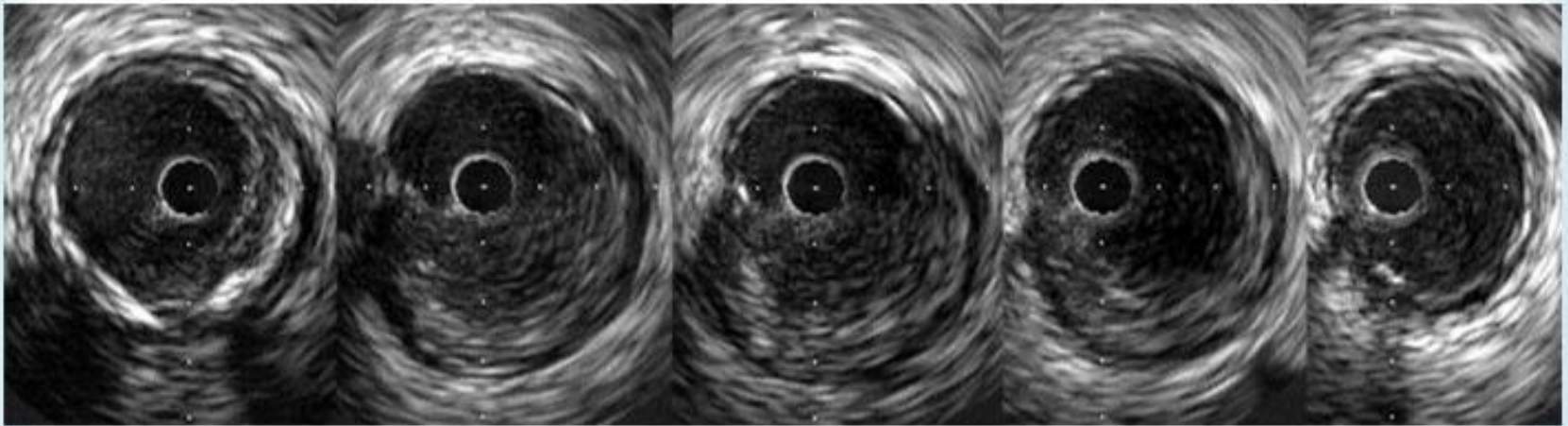
Refringência Placa SEMELHANTE Sangue



**Lipídio sinal pobre
Imagem atenuada
Bordos borrados**

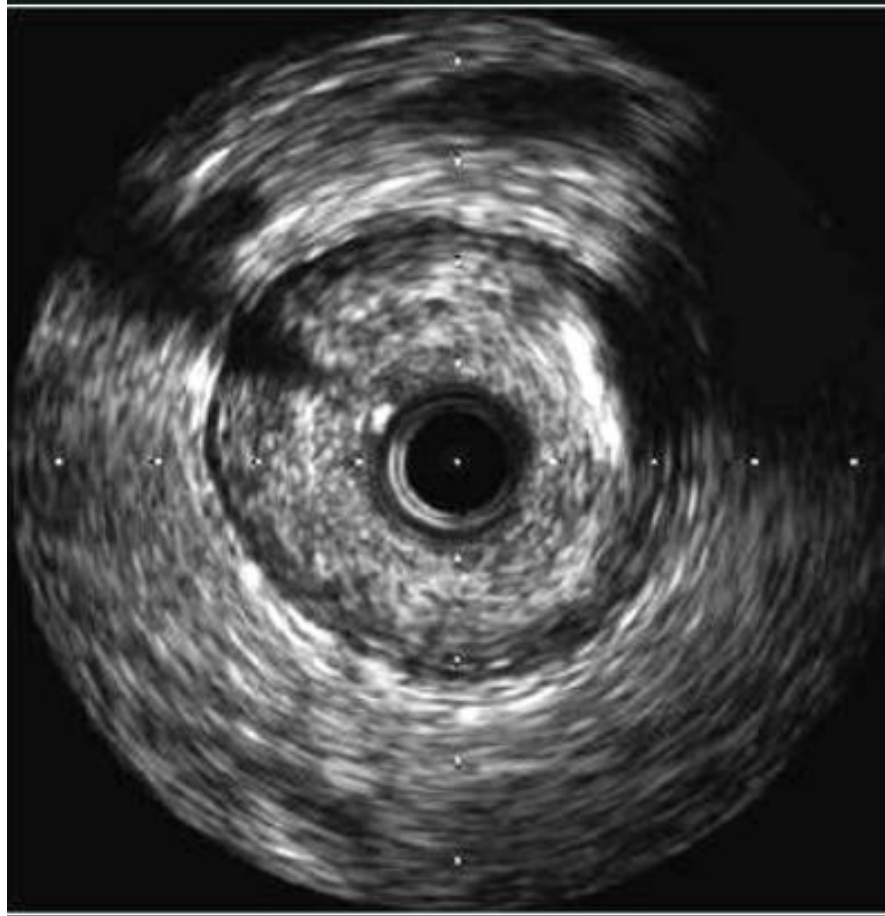
**Imagem hipoecoica
Lago lipídico**

Placa Lipídica

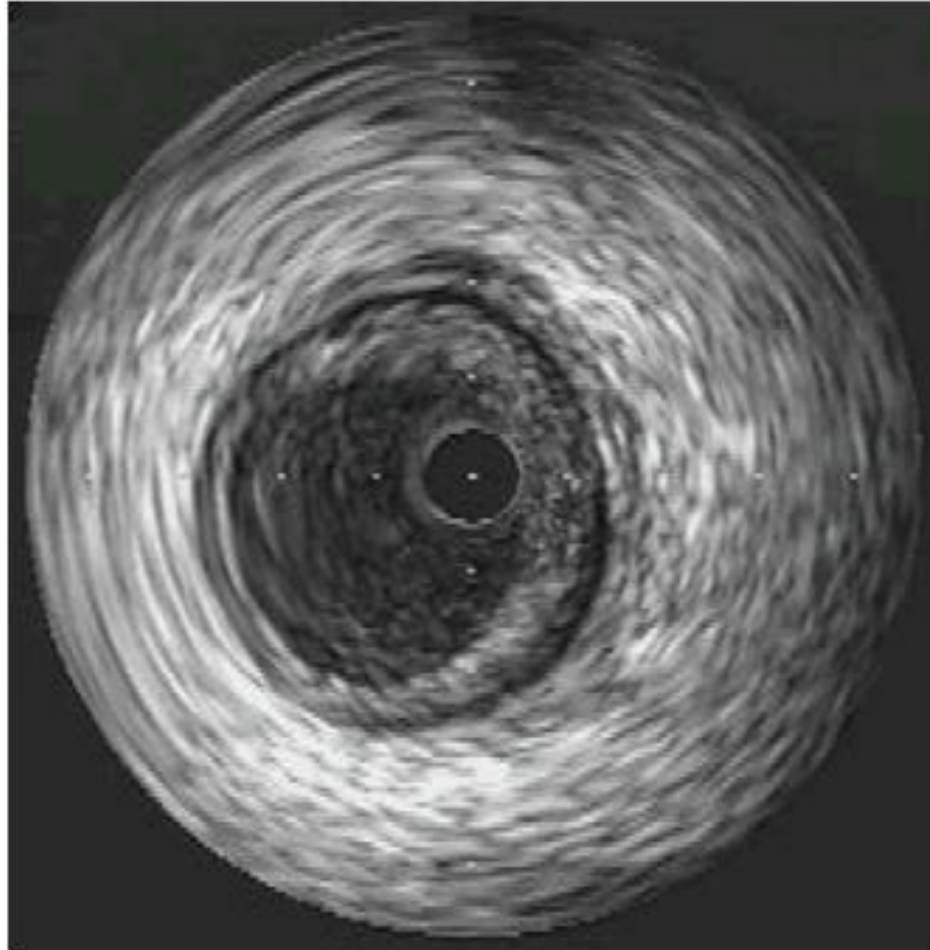


Placa Fibrótica

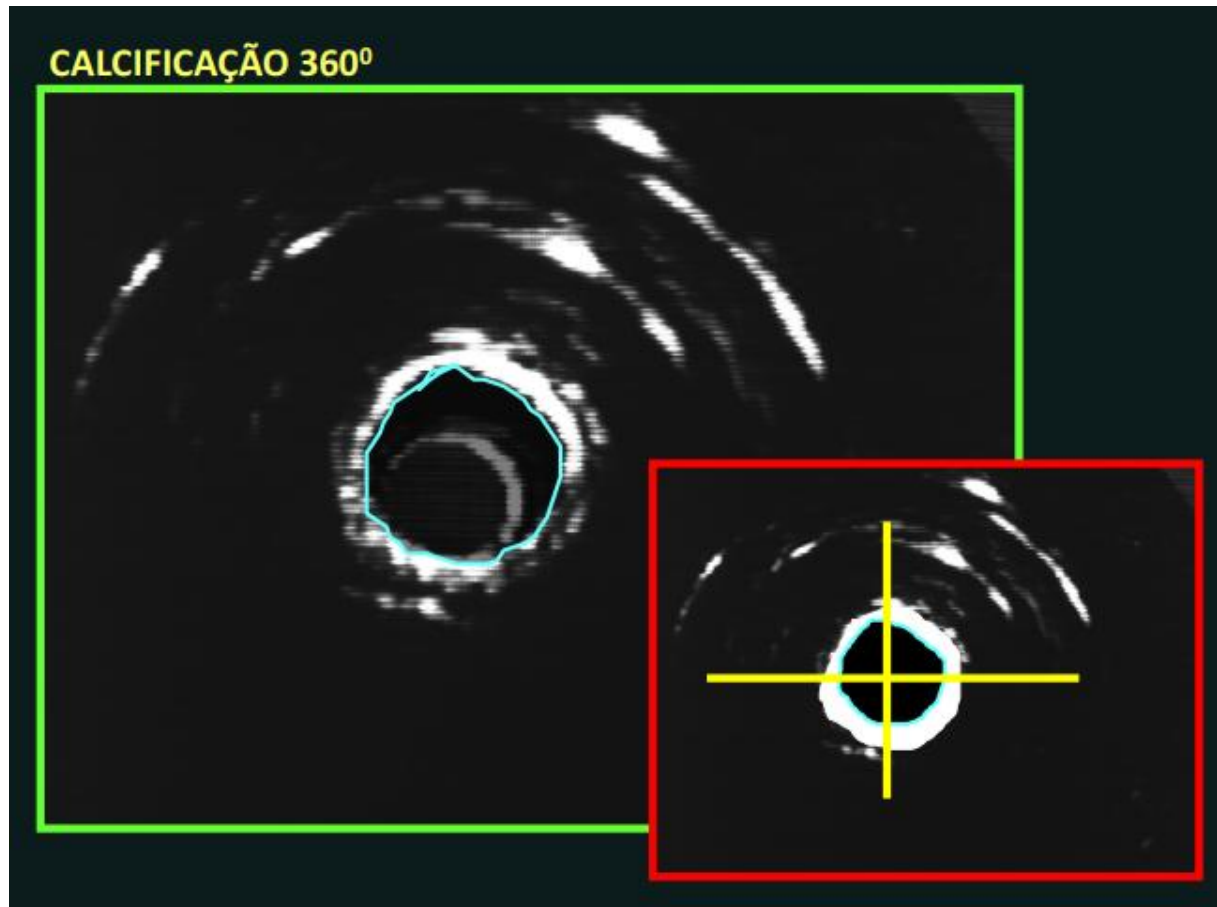
Refringência Placa SEMELHANTE Adventícia



Placa FIBRÓTICA



Intensa Refringência com Posterior Ausência de Som
Cálcio 90°/180°/270°
+180°=>Calcificação Moderada Angiografia
Considerar ROTABLATOR

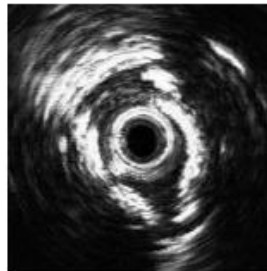
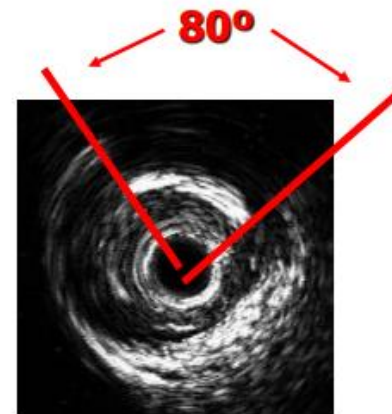


TIPO implica no Preparo da Lesão
Preditor da Expansão do Stent
Trombose/Reestenose

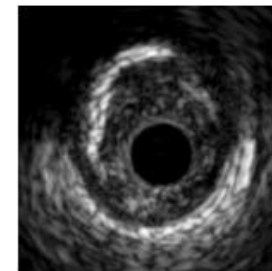
SUPERFICIAL=>Balão NC/Scoring Balloon/Aterectomia Rotacional

Cálcio

- O cálcio é *quantificado* através da medida do seu arco
- O cálcio é *classificado* pela sua localização na placa:
 - Superficial, quando mais próximo da luz que da adventícia
 - Profundo, quando mais próximo da adventícia que da luz



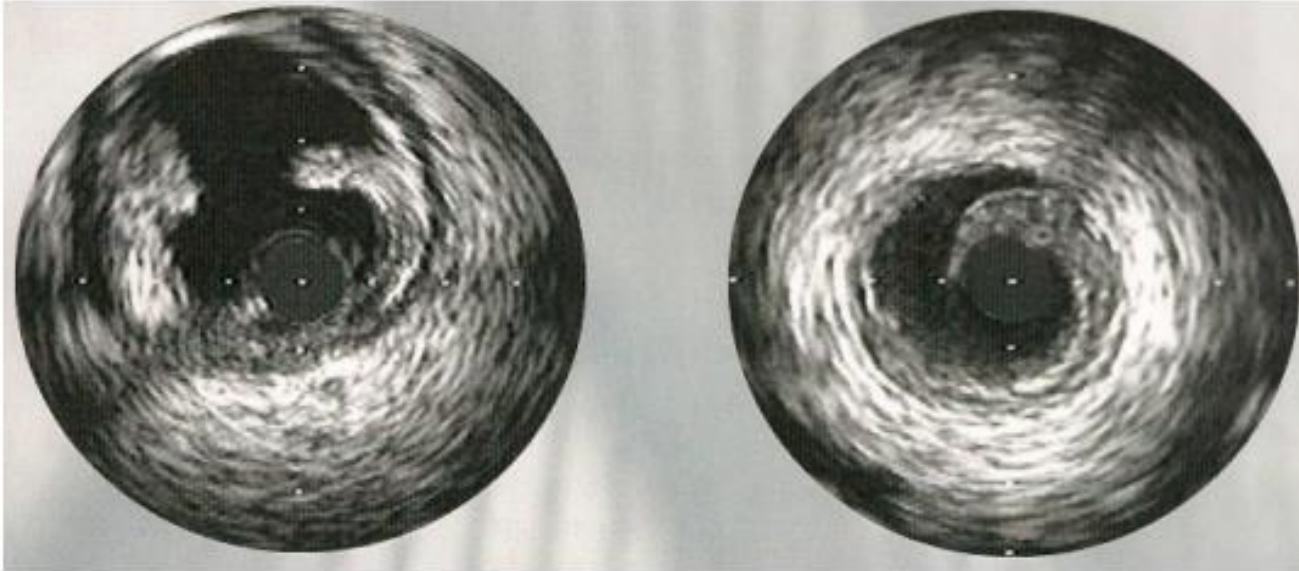
Superficial



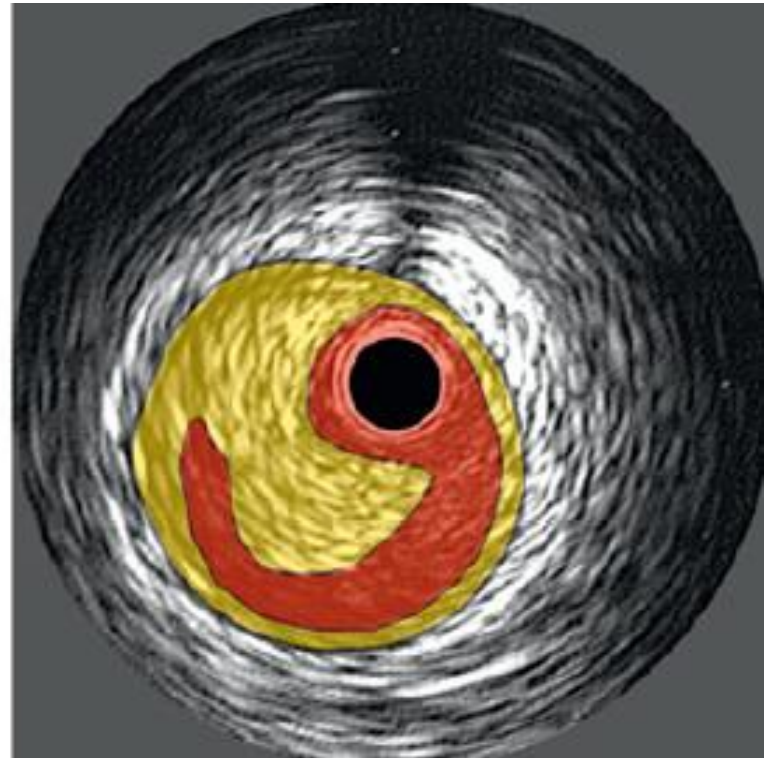
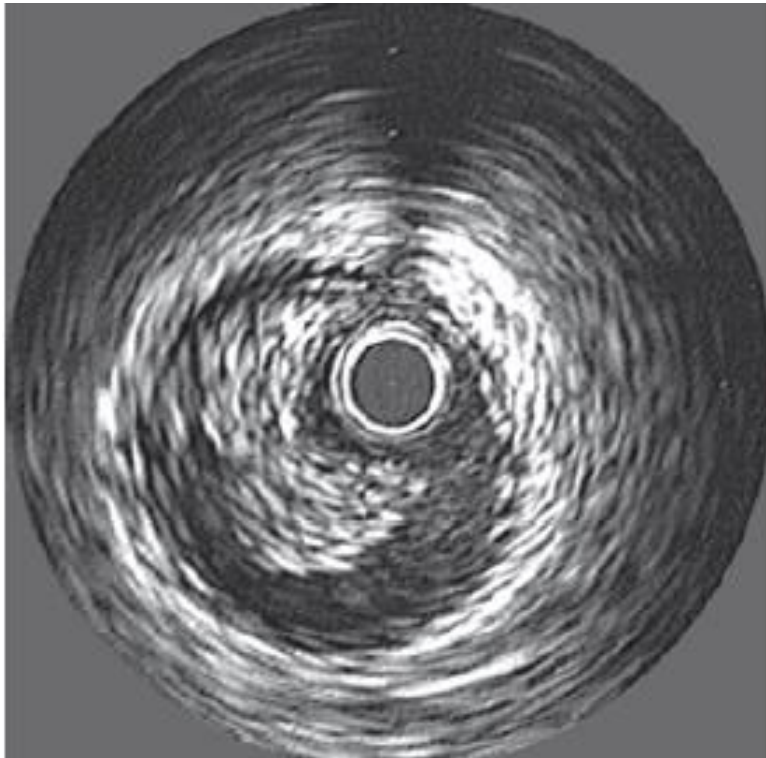
Profundo

ACIDENTES de Placa Aterosclerótica

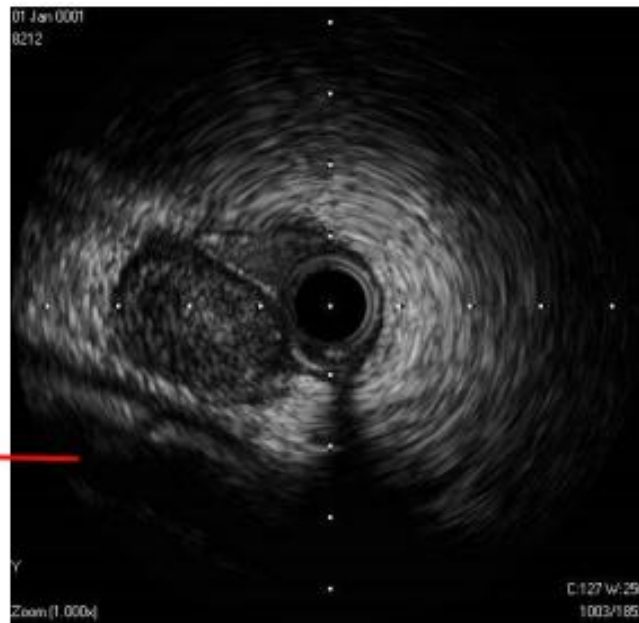
Perda de Integridade da Membrana Elástica Interna

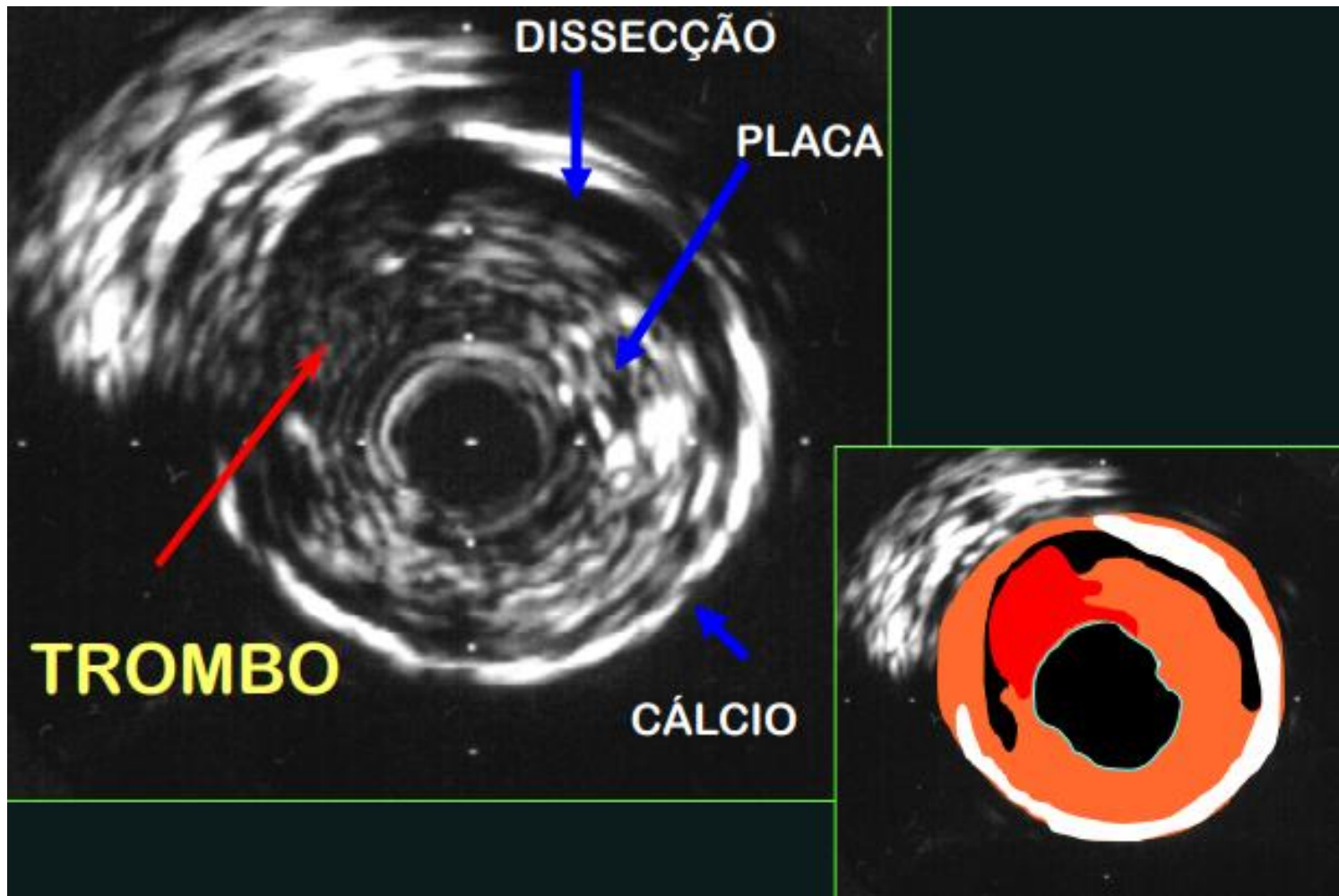


Placa com Dissecção



Hematoma após Dissecção Coronária Espontânea





Decomposição da Imagem Virtual Histology-Volcano/ iMap-Boston

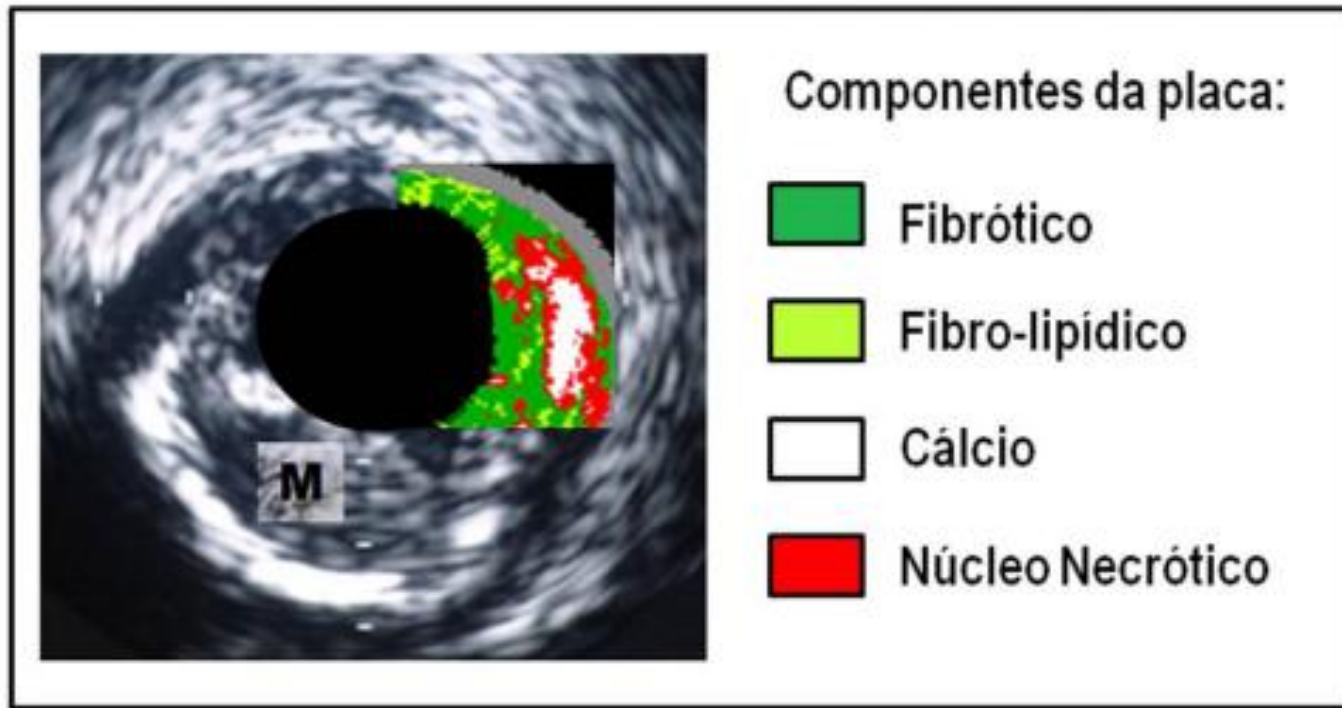


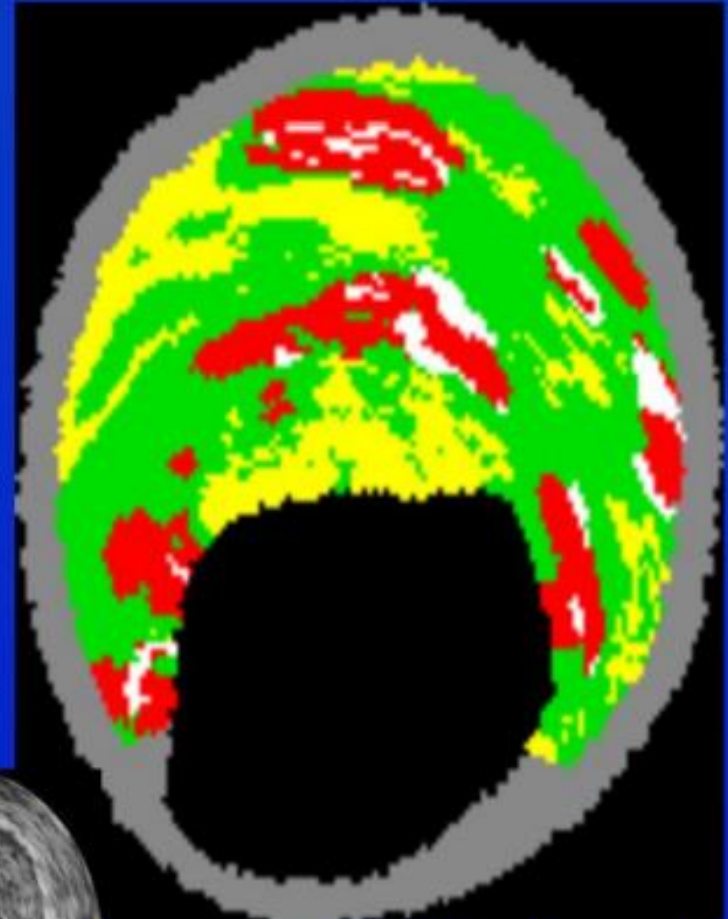
Figura 1 - Reconstrução da imagem ultrassonográfica pela Histologia Virtual®, na qual os quatro componentes da placa são caracterizados pelas cores verde, verde claro, vermelho e branco. A camada média (conforme visualizada ao ultrassom intracoronário convencional) é identificada pela cor cinza. M = camada média.

Sens 85%-95%

Spec. 80%-90%



CALCIUM



FIBROUS

Fibroateroma de Capa Fina (FACF)

1. Focal (adjacent to non-TCFA)

2. Necrotic core $\geq 10\%$

3. In direct contact with the lumen

4. Percent area obstruction $\geq 40\%$

VH Legend

MEDIA M

FIBROTIC FT

FIBROFATTY FF

DENSE CALCIUM

NECROTIC CORE NC

•Per 3 consecutive frames with four characteristics



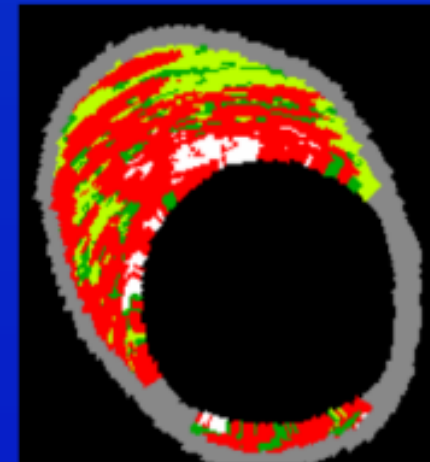
Histology legend

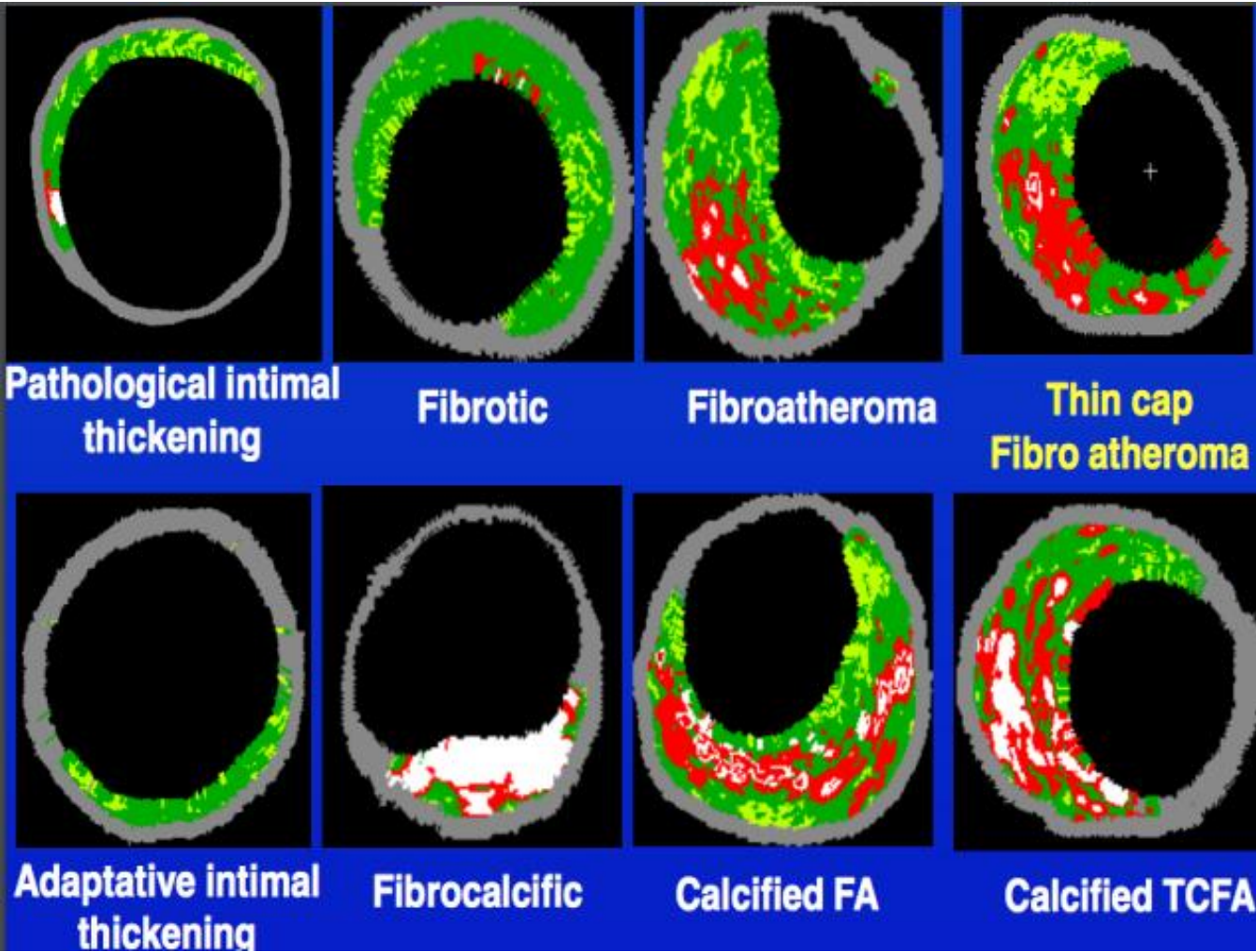
● NECROTIC CORE

● COLLAGEN

● CALCIFIED PLAQUE

● MACROPHAGE FOAM CELLS

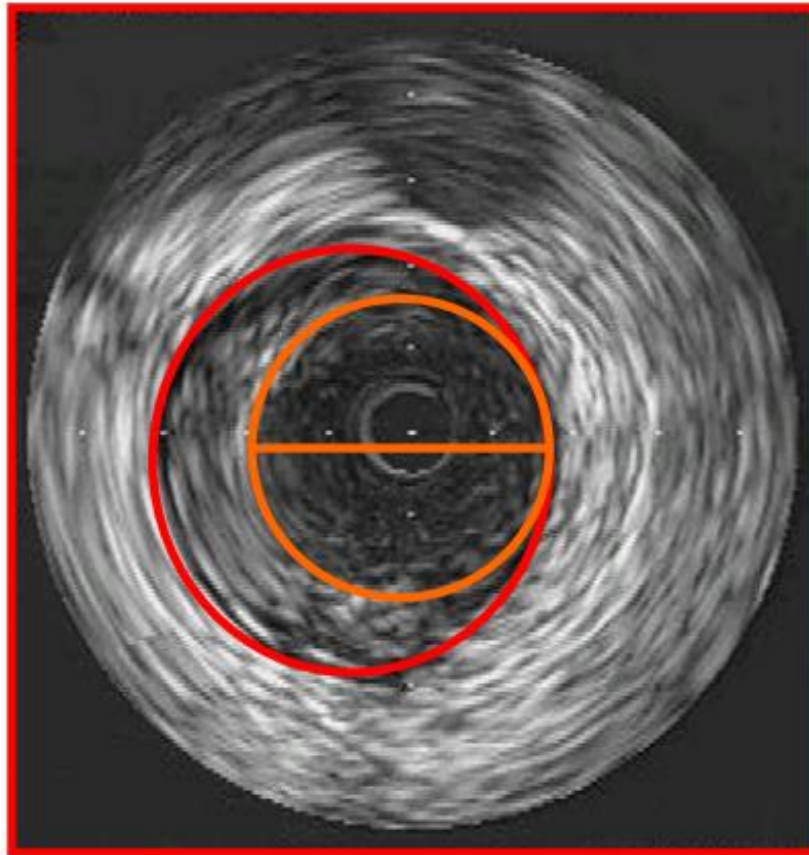




Avaliação QUANTITATIVA

Área Vaso=Borda Externa Camada Média

Carga Placa=Placa+Camada Média

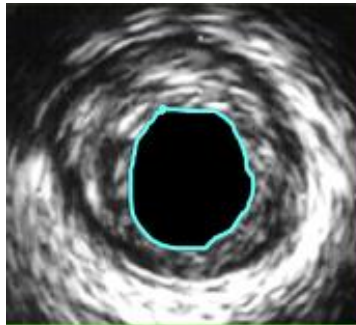


DLM

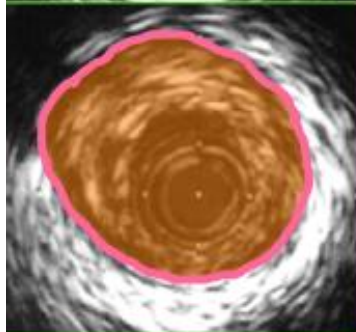
ALM

PB%

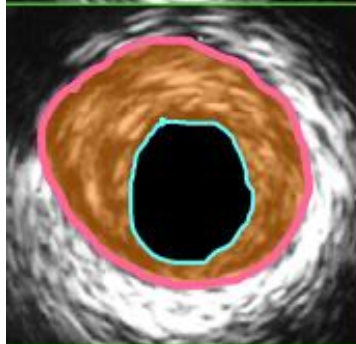
Avaliação QUANTITATIVA



ÁREA LUMINAL = 2 mm²



ÁREA TOTAL DO VASO (MEE) = 10 mm²



ÁREA DE ATEROMA = 8 mm²

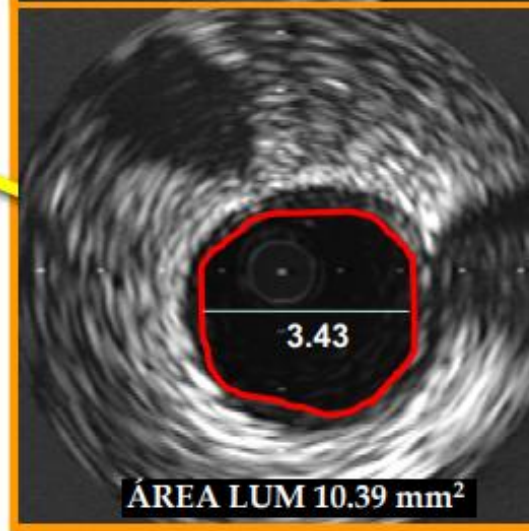
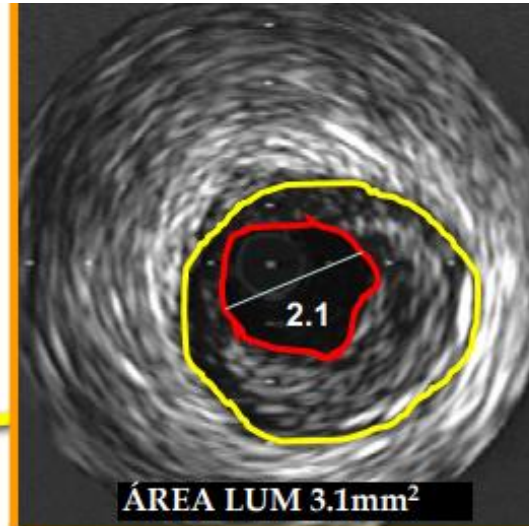
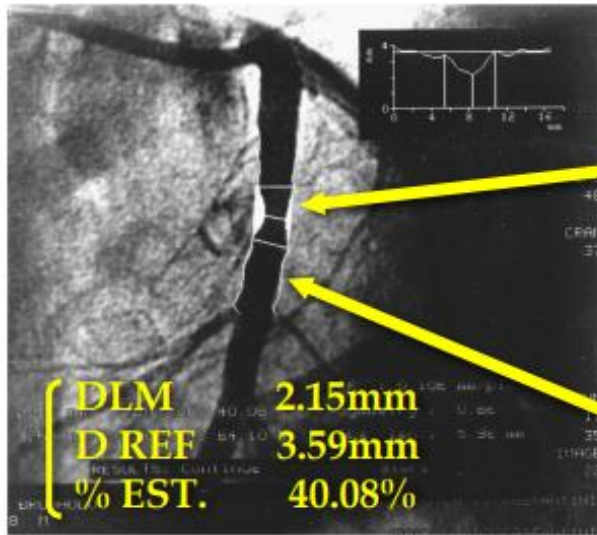
ATV ---- 100%

AA ---- X (CARGA DE PLACA)

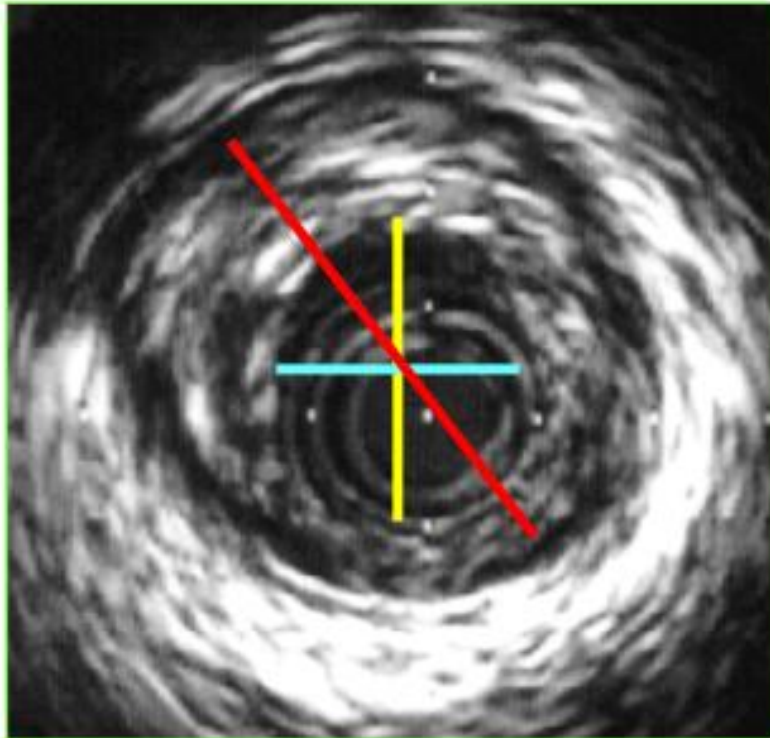
$$\left[\text{Plaque burden} = \frac{\text{Atheroma area}}{\text{Stenosis EEM area}} \times 100 \right]$$

$$CP = ((10,39 - 3,1) / 10,39) \times 100 = 70\%$$

B.B.
73 ANOS
MASC



01/11/01



MÍN DIÂMETERO LUMINAL

DIÂMETERO MÉDIA-MÉDIA

ÍNDICE DE ASSIMETRIA LUMINAL = $\frac{\text{MÍN DIÂMETERO LUMINAL}}{\text{MÁX DIÂMETERO LUMINAL}}$

**1 CIRCULAR LÚMEM
< 1 LÚMEM ELÍPTICO**

Índice de Remodelamento

Área vaso local lesão/ ((Área vaso proximal+Área vaso distal)/2)

The remodeling index is calculated as the EEM CSA at the MLA divided by the average of the proximal and distal reference EEM CSA.

EEM CSA at Lesion site

$$= \frac{\text{EEM CSA at Lesion site}}{(\text{proximal reference EEM CSA} + \text{distal reference EEM CSA})/2}$$

≥ 1.05

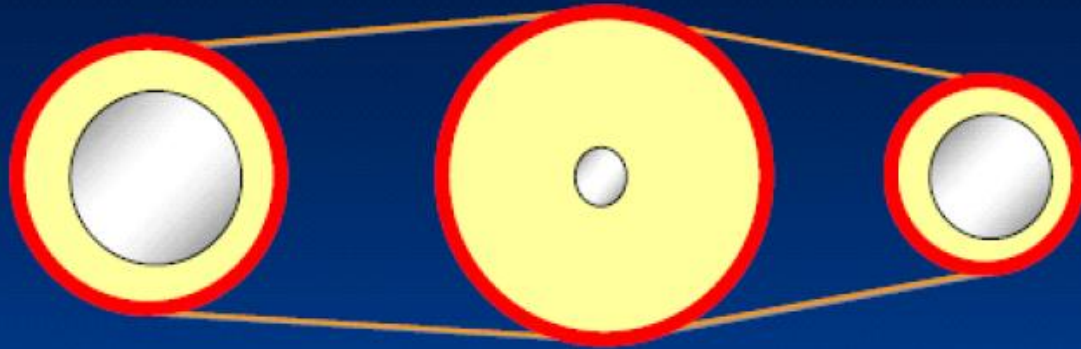
< 0.95

Positive remodeling

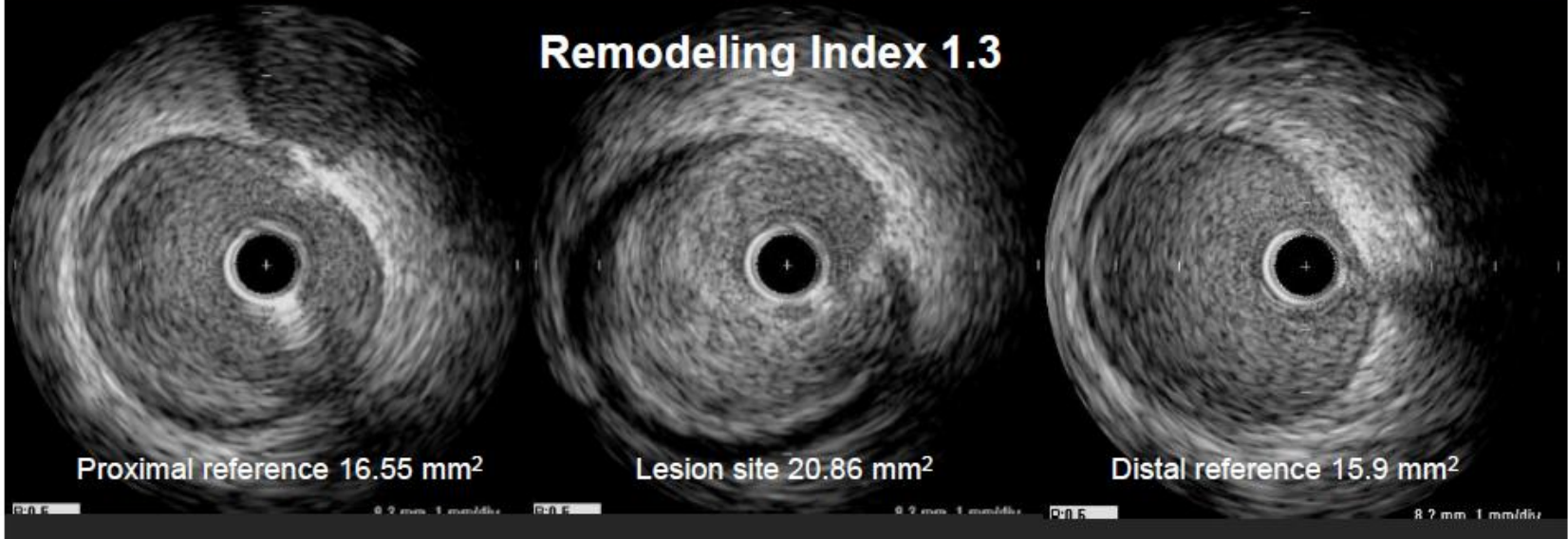
Intermediate remodeling

Negative remodeling

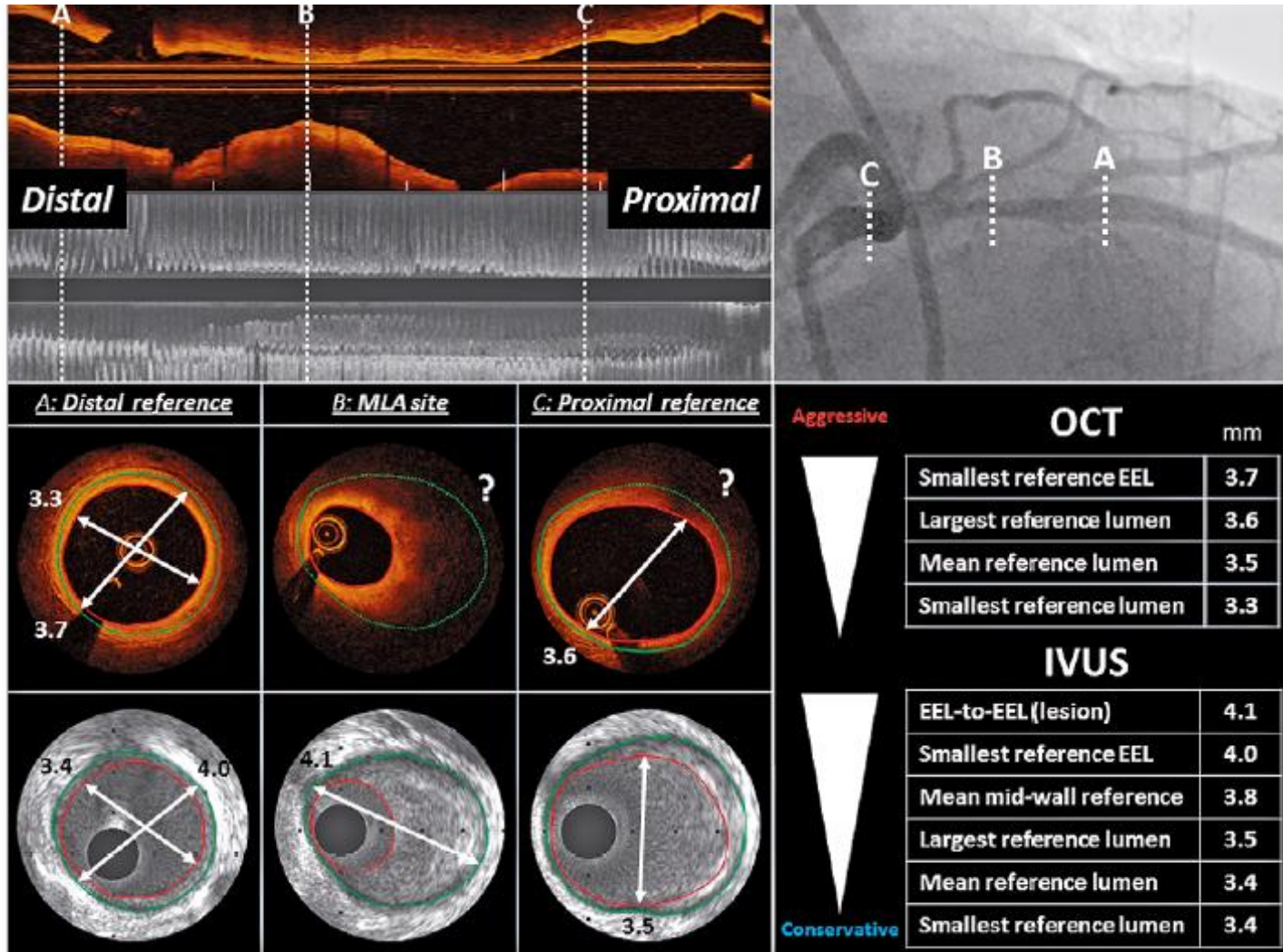
Positive remodeling



Remodeling Index 1.3



IVUS + penetração X OCT + resolução



Top 5s

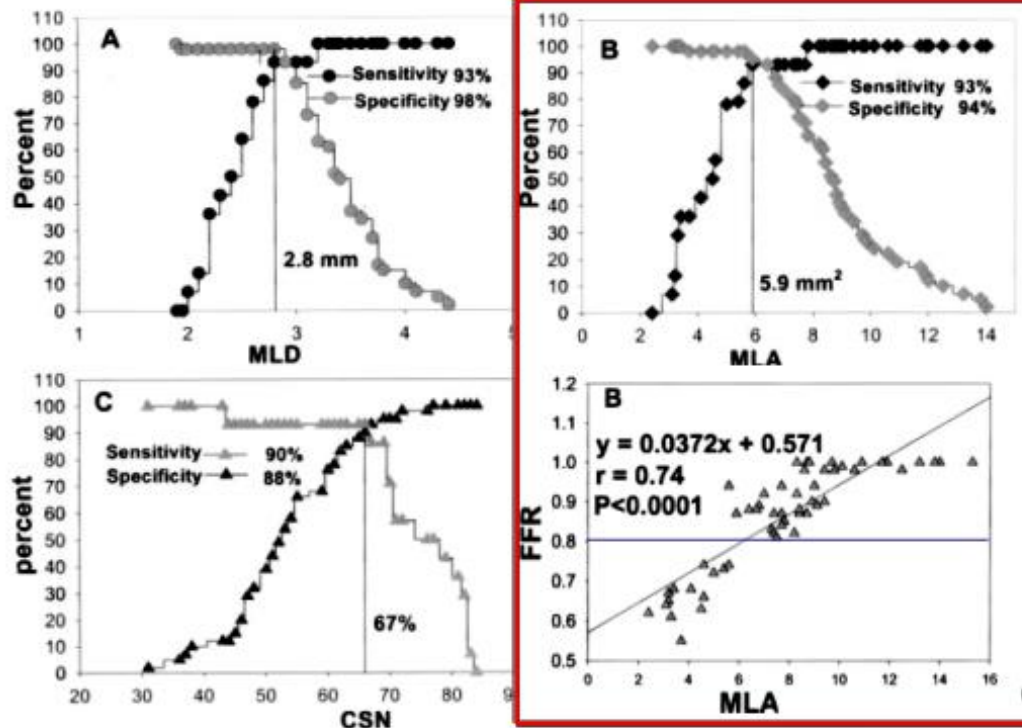
INDICAÇÕES MAIS EVIDENTES DE IVUS

- Avaliação de severidade da lesão do TCE
- Angioplastia de TCE
- Avaliação de acidentes de placa/dissecção espontânea
- Complexidade Anatômica e Clínica
- Avaliação de falência dos stents (reestenose/trombose) - **expansão**

Área do USIC fidedigna para definição da gravidade da lesão do tronco da coronária esquerda

Correlations Between Fractional Flow Reserve and Intravascular Ultrasound in Patients With an Ambiguous Left Main Coronary Artery Stenosis

Venu Jasti, MD; Eugen Ivan, MD; Venkata Yalamanchili, MD;
Nattawut Wongpraparut, MD; Massoud A. Leesar, MD



(Circulation. 2004;110:2831-2833)



Left Main less than 4.5mm^2 is likely to have a positive ischaemia test



Left Main greater than 6mm^2 is likely to have a negative ischaemia test



FFR has limitations in the left main

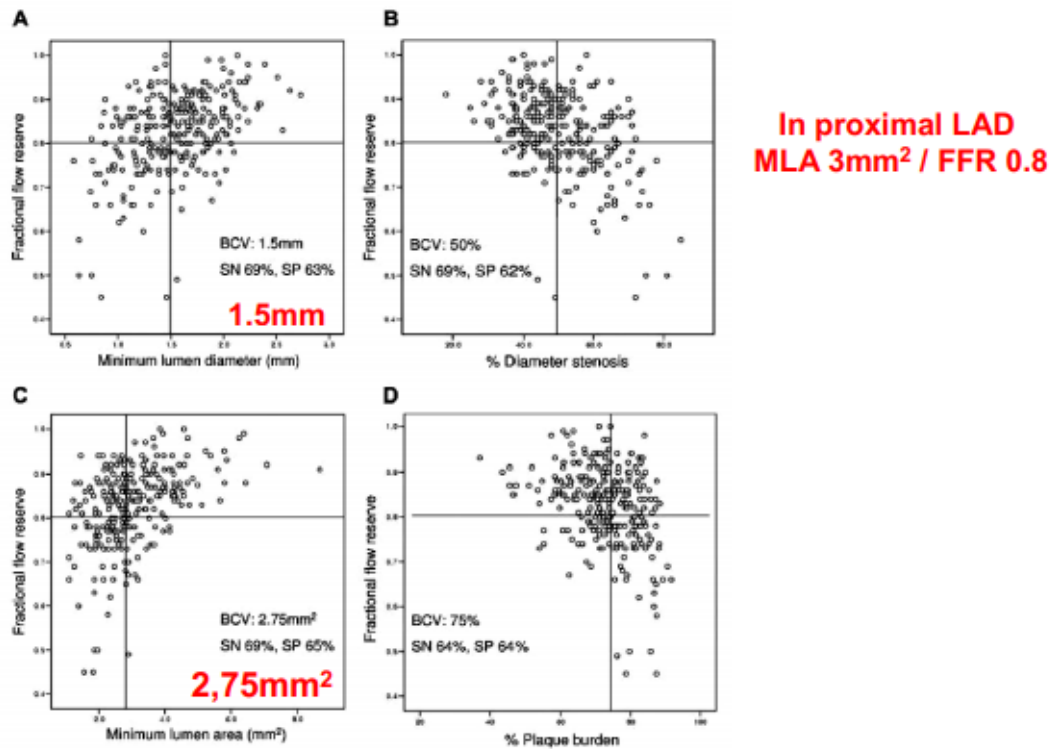


iFR may be superior but limited data

BAIXA correlação IVUS/FFR em vasos não tronculares

MOTIVO: massa miocárdica envolvida

Optimal Intravascular Ultrasound Criteria and Their Accuracy for Defining the Functional Significance of Intermediate Coronary Stenoses of Different Locations



Correlation between FFR and IVUS lumen area in intermediate coronary artery stenosis

IVUS and FFR

| Reference | Patients/ lesions | IVUS MLA for FFR <0.75 | IVUS MLA for FFR <0.8 |
|-----------------------|----------------------|------------------------------|--------------------------|
| Takagi ⁴ | 42/51 | <3 mm ² | N/A |
| Briguori ⁵ | 43/53 | <4 mm ² | N/A |
| Lee ^{6#} | 94/94 | <2 mm ² | N/A |
| Ben-Dor | 84/92 | <2.8 mm ² | <3.2 mm ² |
| Jasti ⁷⁺ | 55/55 | <5.9 mm ² | N/A |

#Small vessels with reference vessel diameters <3 mm; +Left main coronary stenosis; N/A: not available; IVUS: intravascular ultrasound; MLA: minimal luminal area; FFR: fractional flow reserve

CORE LAB IVUS X ANGIOGRAFIA

Lesões Graves

11% Sim IVUS / Não Angiografia

57% Não IVUS / Sim Angiografia

Five studies have highlighted the inaccuracy of angiography in the assessment of LMCA disease

- CASS Registry Studies
 - Fisher et al. Cathet Cardiovasc Diagn 1982;8:565-75
 - Cameron et al. Circulation 1983;68:484-489
- Lindstaedt et al. Int J Cardiol 2007;120:254-61
 - In 51 patients unanimous correct assessment of LM severity by 4 experienced interventional cardiologists was only 29%
- Hamilos et al. Circulation 2009;120:1505-12
 - In 209 patients two reviewers either (1) disagreed whether the LM was significant (26%) or (2) agreed, but were wrong in their assessment when compared to FFR (23%)
- Chakrabarti et al. Circ Cardiovasc Interv 2014;7:11-8
 - 11.2% (17 out of 152) pts with "core laboratory" LM disease were listed as normal in the NCDR, whereas 56.7% (177 out of 312) pts that were listed as having LMCA disease in the NCDR had no LM lesion by core laboratory analysis

Long-Term Outcomes of Coronary Stent Implantation versus Bypass Surgery for the Treatment of Unprotected Left Main Coronary Artery Disease

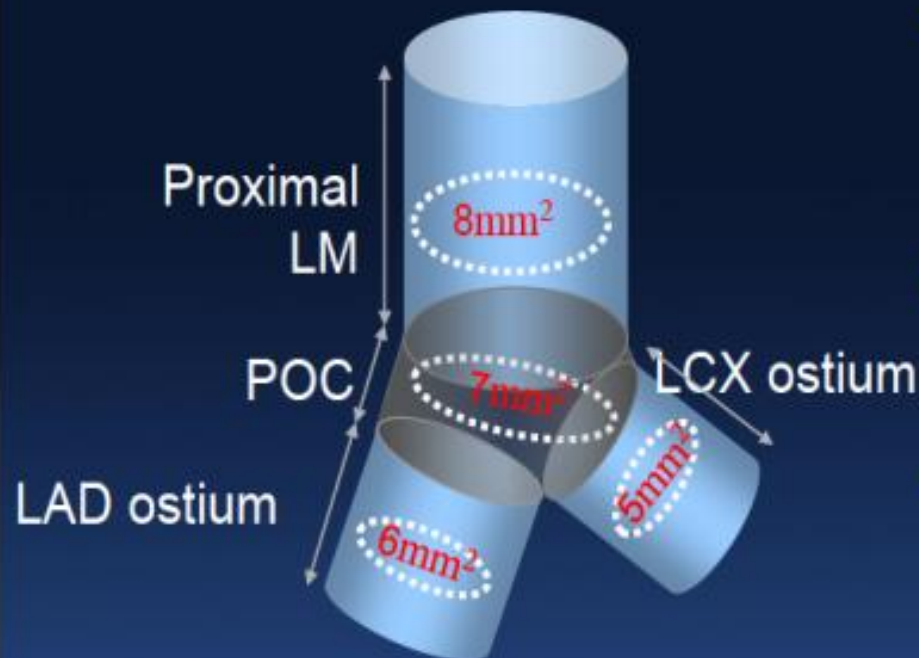
Revascularization for Unprotected Left **MAIN** Coronary Artery Stenosis: **COM**parison of **P**ercutaneous Coronary **A**ngioplasty versus Surgical **RE**vascularization from Multi-Center Registry:

The **MAIN-COMPARE** Registry

Co-Principal Investigators:

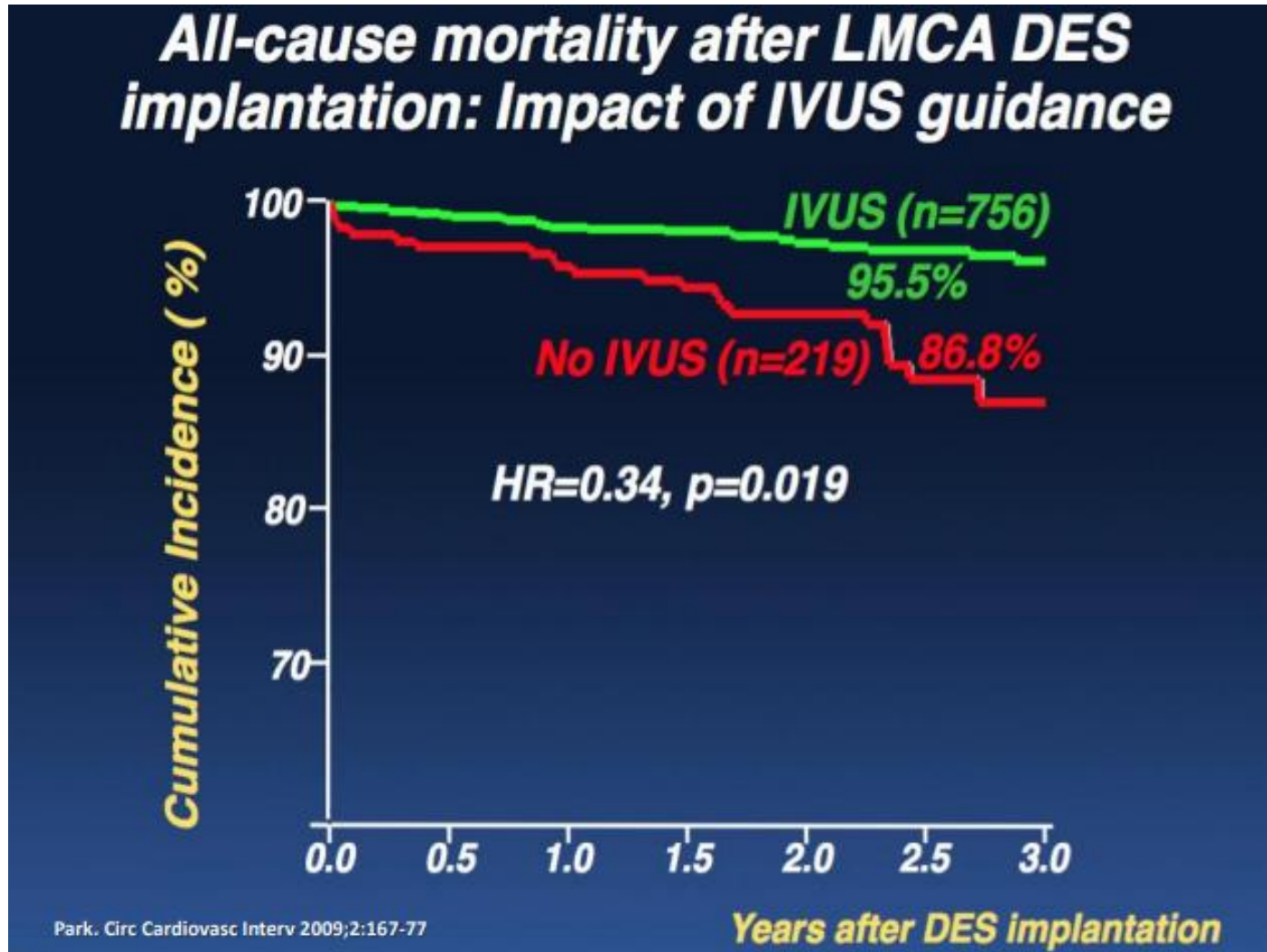
Seung-Jung Park, MD, PhD, Ki-Bae Seung, MD, PhD
for the MAIN-COMPARE Study investigators

Criteria for stent underexpansion at the distal LMCA bifurcation (n=403)



- *MACE-free survival was lower in pts with underexpansion vs those without underexpansion (89.4% vs 98.1%)*
- *TLR-free survival was lower in pts with underexpansion vs no underexpansion (90.9% vs 98.5%).*
- *Although acute malapposition was observed in 28 pts, malapposition was not related to MACE at follow-up.*

Redução de mortalidade nos pacientes tratados com SFs e guiados porUSIC (4,7% vs. 16%; log-rank $p = 0,048$).

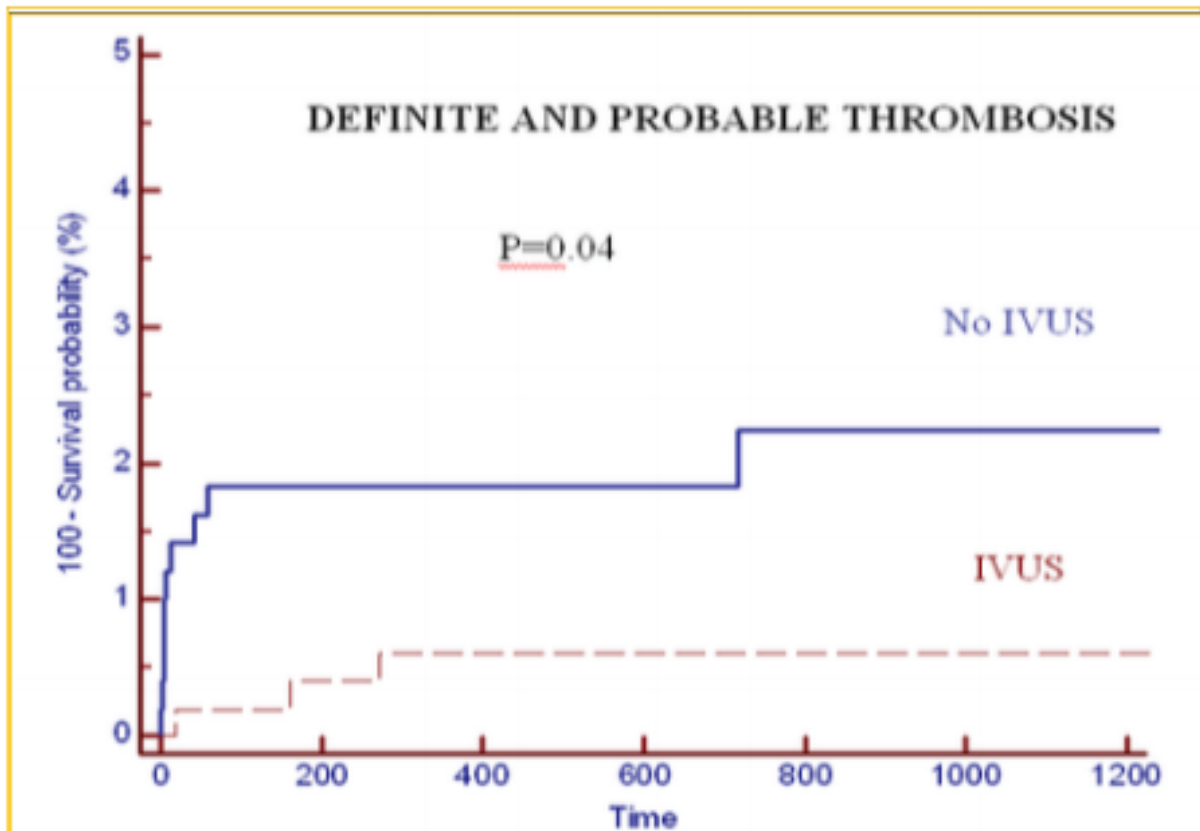


Clinical Impact of Intravascular Ultrasound Guidance in Drug-Eluting Stent Implantation for Unprotected Left Main Coronary Disease

Pooled Analysis at the Patient-Level of 4 Registries

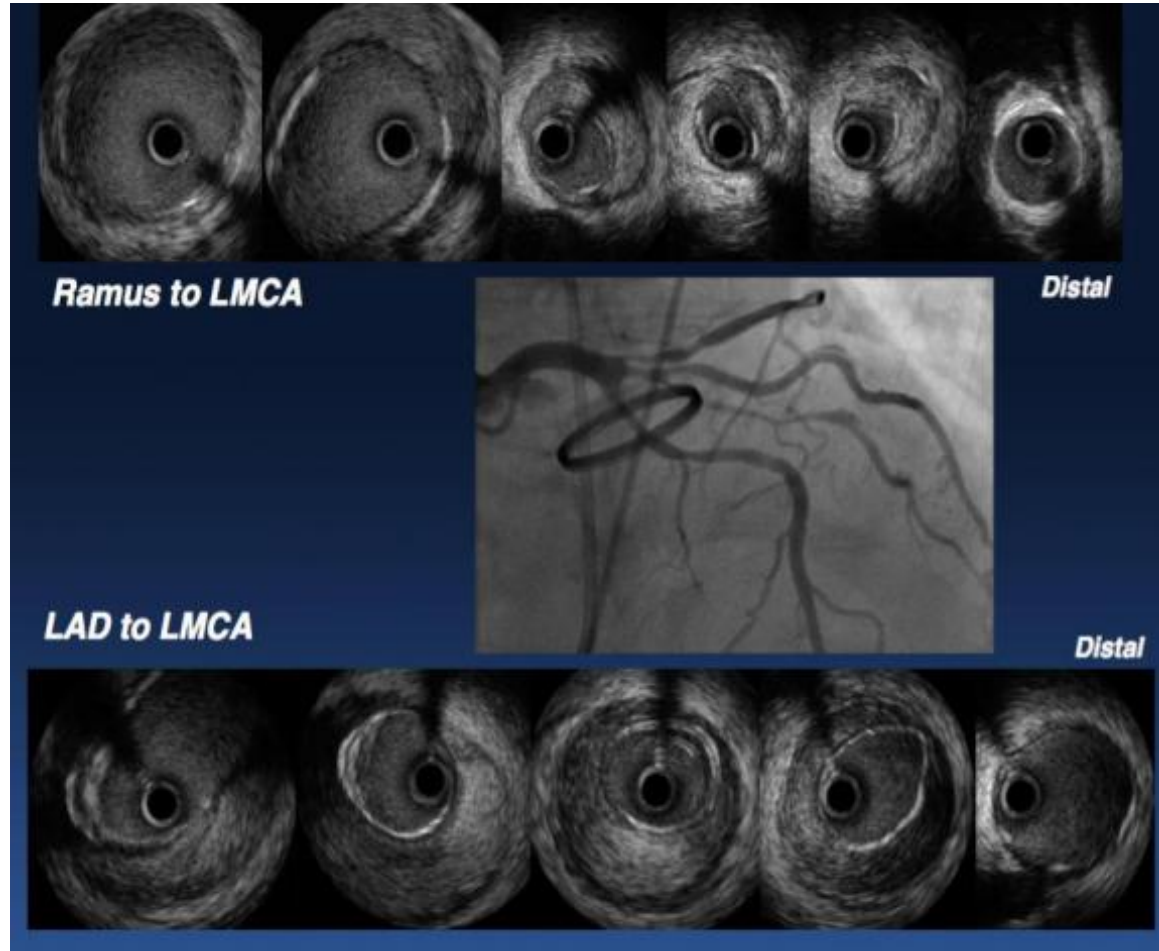
Jose M. de la Torre Hernandez, MD, PhD,* José A. Baz Alonso, MD,†
Joan A. Gómez Hospital, MD, PhD,‡ Fernando Alfonso Manterola, MD, PhD,§
Tamara Garcia Camarero, MD,* Federico Gimeno de Carlos, MD, PhD,||
Gerard Roura Ferrer, MD,‡ Angel Sanchez Recalde, MD,¶
Íñigo Lozano Martínez-Luengas, MD, PhD,# Josep Gomez Lara, MD,‡
Felipe Hernandez Hernandez, MD,** María J. Pérez-Vizcayno, MD,§
Angel Cequier Fillat, MD, PhD,‡ Armando Perez de Prado, MD,††
Agustín Albarrán Gonzalez-Trevilla, MD,** Manuel F. Jimenez Navarro, MD, PhD,‡‡
Josepa Mauri Ferre, MD,§§ Jose A. Fernandez Diaz, MD,|||
Eduardo Pinar Bermudez, MD, PhD,¶¶ Javier Zueco Gil, MD,*
on behalf of the collaborative IVUS-TRONCO-ICP Spanish study

Santander, Vigo, Barcelona, Madrid, Valladolid, Oviedo, Leon, Malaga, Badalona, and Murcia, Spain



| Pts. at risk | 365 days | 730 days | 1095 days |
|--------------|----------|----------|-----------|
| IVUS | 485 | 286 | 203 |
| No IVUS | 470 | 275 | 201 |

Avaliação de Acidentes de Placa/Dissecção Espontânea



IVUS na Oclusão Crônica

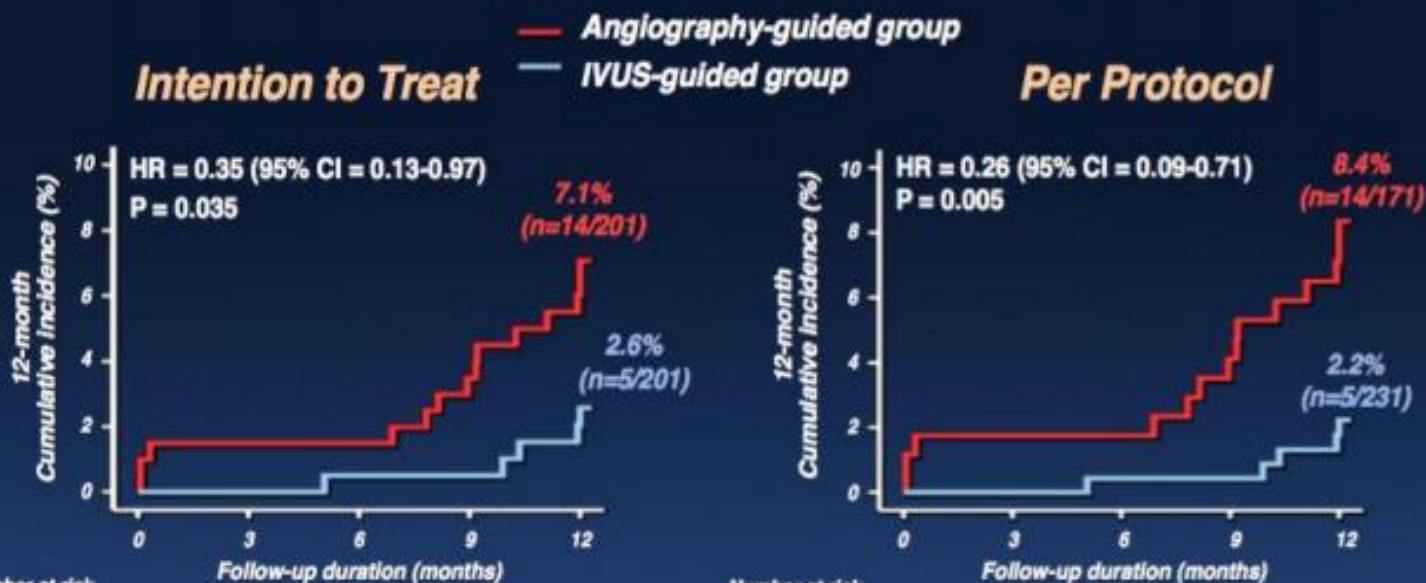
Redução de Mortalidade

Use of IVUS During PCI of CTO

- **Making sure that the guidewire is in the true lumen distally – especially important with the antegrade approach – as well as the course of the guidewire through the CTO**
- **Minimizing contrast injection**
- **Avoiding complications**
- **Stent optimization**
- **Crossing a proximal fibrous cap**

Randomized study of IVUS vs Angiography-guided CTO Intervention

Primary endpoint (Cardiac death, MI, TVR)



Number at risk

| | | | |
|-------------|-----|-----|-----|
| Angiography | 201 | 198 | 179 |
| IVUS | 201 | 198 | 186 |

Number at risk

| | | | |
|-------------|-----|-----|-----|
| Angiography | 171 | 167 | 151 |
| IVUS | 231 | 229 | 214 |

| | IVUS | Angio | P-value |
|------------------|------|-------|---------|
| Cardiac death/MI | 0% | 2% | 0.045 |
| TVR | 2.6% | 5.2% | 0.186 |

| | IVUS | Angio | P-value |
|------------------|------|-------|---------|
| Cardiac death/MI | 0% | 2.3% | 0.019 |
| TVR | 2.2% | 6.1% | 0.049 |

Prevenção de NIC em pacientes de Alto Risco para Nefropatia

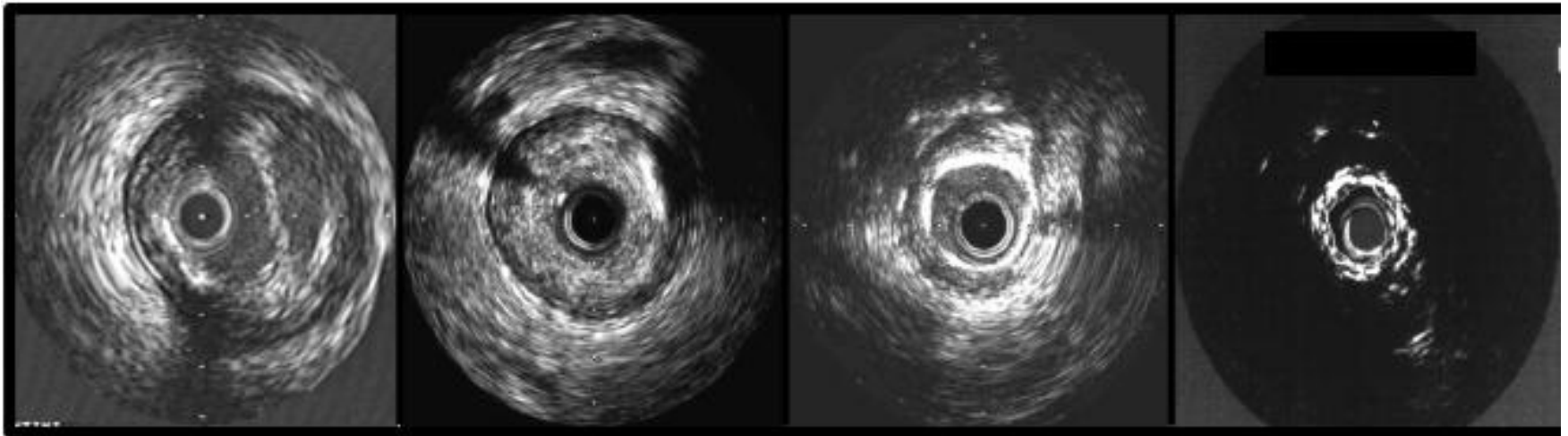
IVUS Guidance to Minimize the Use of Iodine Contrast in PCI

- MOZART - Mariani et al. JACC Cardiovasc Interv 2014;7:1287-93
 - 83 pts randomized to IVUS vs angiographic guidance with a pre-specified PCI strategy designed to reduce contrast usage in both groups
 - Reduction in contrast use (primary endpoint) from 64.5ml (IQR 42.8-97ml, range 19-170ml) to 20.0ml (IQR 12.5-30.0ml, range 3-54ml): $p < 0.0001$
 - No difference in 4-month outcomes although there was a trend toward a less common increase in serum Cr $> 0.5\text{mg/dl}$ (7.3% vs 19.0%, $p = 0.2$)
- Ali et al. Eur Heart J, in press
 - 31 pts with median creatinine of 4.2mg/dL (IQR 3.1-4.8)
 - Successful zero contrast PCI was performed at least 1 week after diagnostic angiography using real-time IVUS guidance and pre- and post-PCI FFR and CRF to confirm physiologic improvement
 - No MACE and preservation of renal function in all pts at a median follow-up of 79 days (IQR 33-107).

COMPLEXIDADE ANATÔMICA

- Angioplastia GUIADA pelo IVUS:
 - Avaliação prévia à intervenção – CÁLCIO!
 - Escolha adequada do tamanho do dispositivo
 - Escolha da *landing zone*
 - Balão para pré-dilatação
 - Stent
 - Avaliação durante a intervenção
 - Resultado imediato
 - Dissecções bordas
 - Balão para pós-dilatação
 - Avaliação após intervenção
 - Expansão – critérios MUSIC trial

1) Mole / 2) Fibrose Extensa /
3) Fibrose+Calcificação / 4) Calcificação Intensa



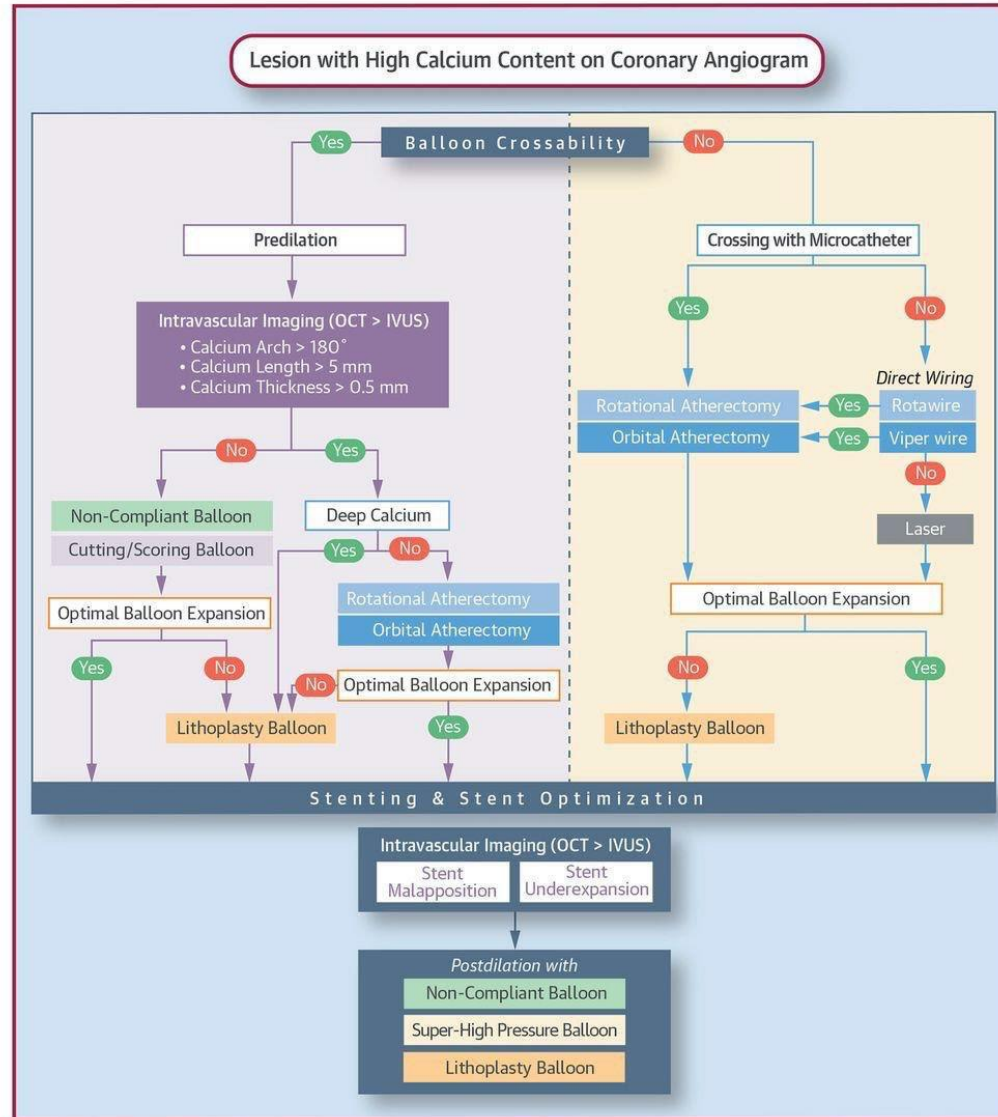
STENT DIRETO
PREDILATAÇÃO

PREDILATAÇÃO
CUTTING BALLOON

CUTTING BALLOON
PREDILATAÇÃO

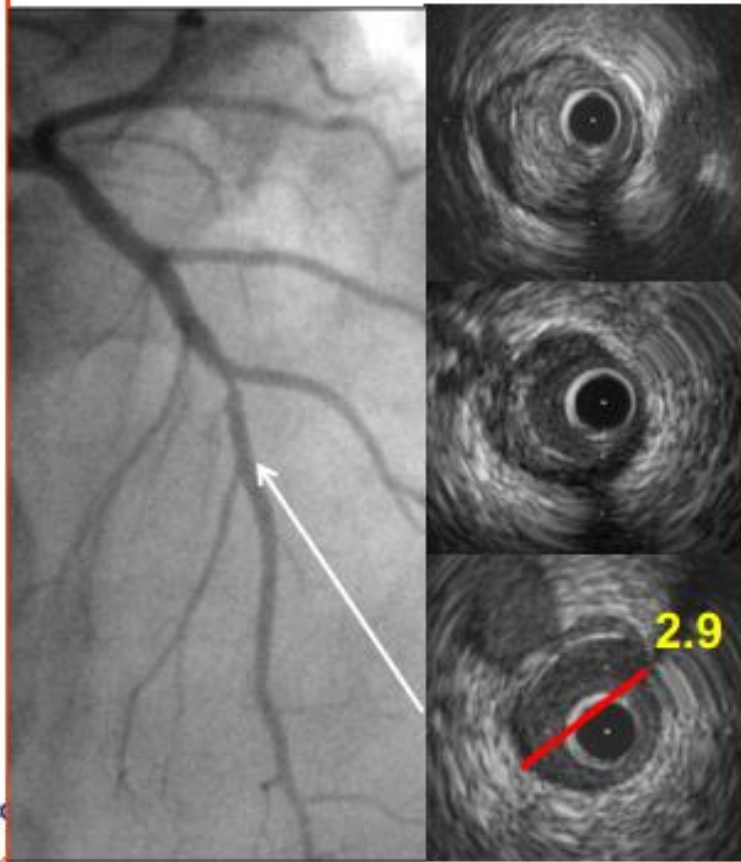
ROTABLATOR

CENTRAL ILLUSTRATION: Algorithm for Optimal Management of Coronary Calcified Lesions

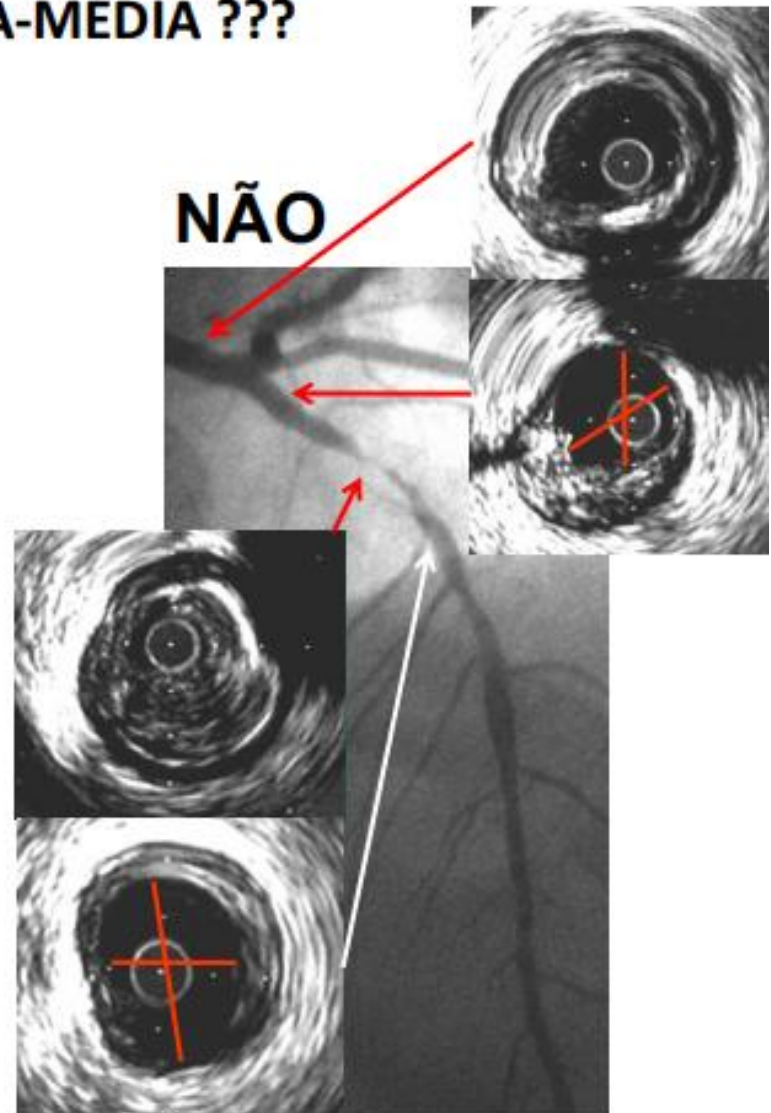


DIÂMETRO DO STENT É IQUAL AO DIÂMETRO MEDIA-MEDIA ???

SIM

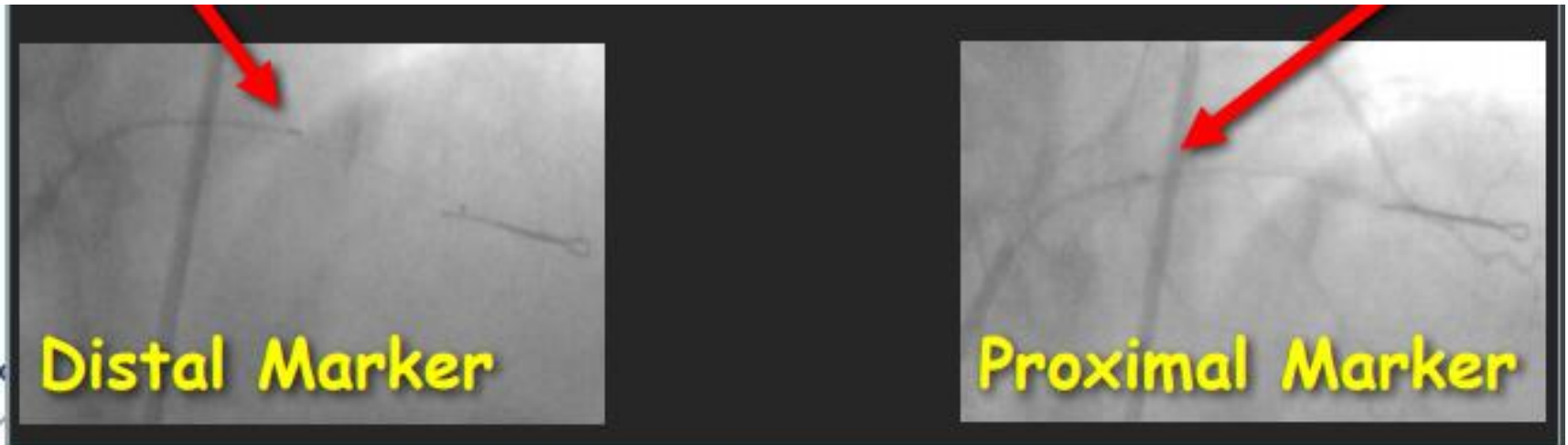


NÃO



Comprimento do STENT

Correlação Angiografia e IVUS



Posicionamento do STENT



3mm landing zone distally



Reasonably healthy landing zone
(<50% plaque burden)

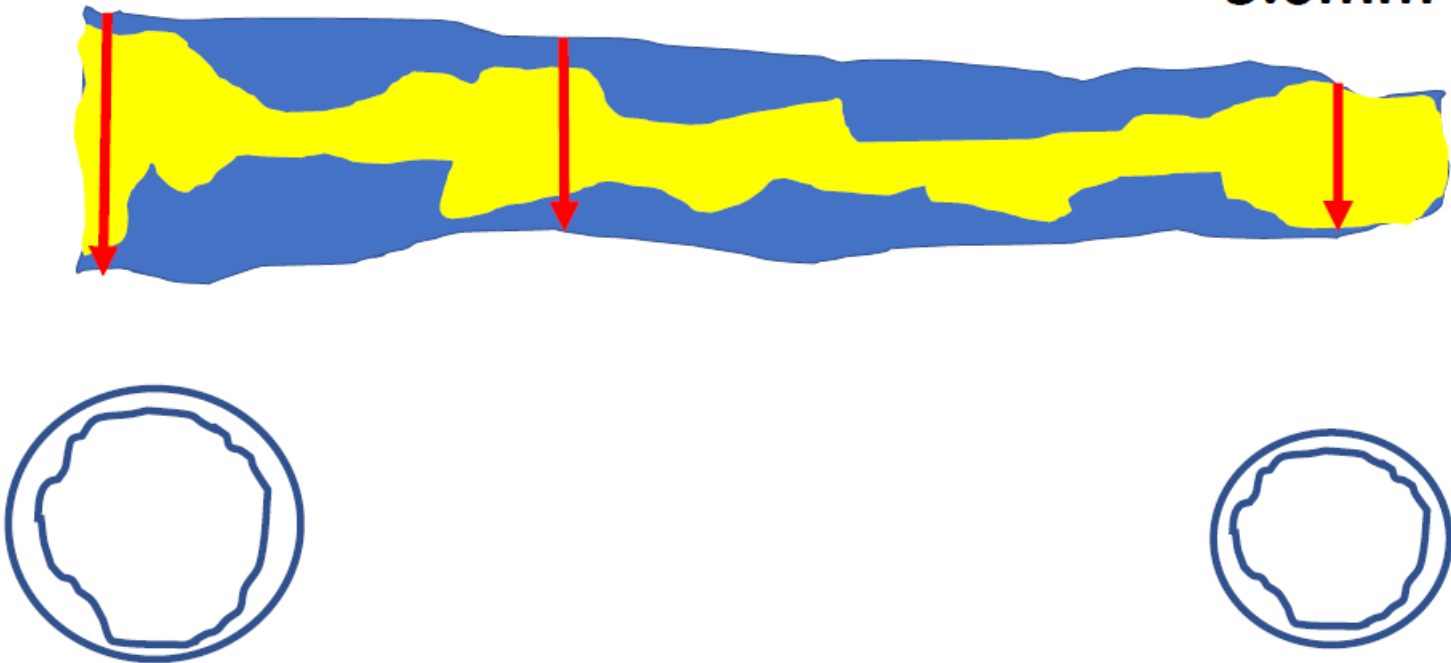


Modest likelihood of dissecting
landing zone

4.25mm

3.5mm

3.0mm





Large size disparity



Need for stent to go up to close to 4.25mm proximally



Single 3mm stent which can post-dilate up to near 4.25, or two stents



More conservative dilatation at segment of negative remodelling (3.5 at that point)

Labeled Post-Dilatation Limits*



Courtesy: Ajay Kirtane

Critérios MUSIC para Expansão do STENT

- Aposição completa do stent
- Expansão adequada do stent
- AMS (área mínima do stent) $\geq 90\%$ da área média do lúmen de referência ou $\geq 100\%$ do segmento de referência com a área mais baixa quando a AMS é $< 9 \text{ mm}^2$

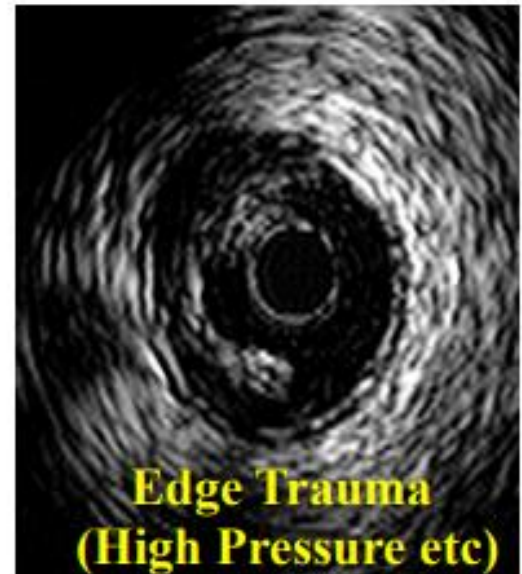
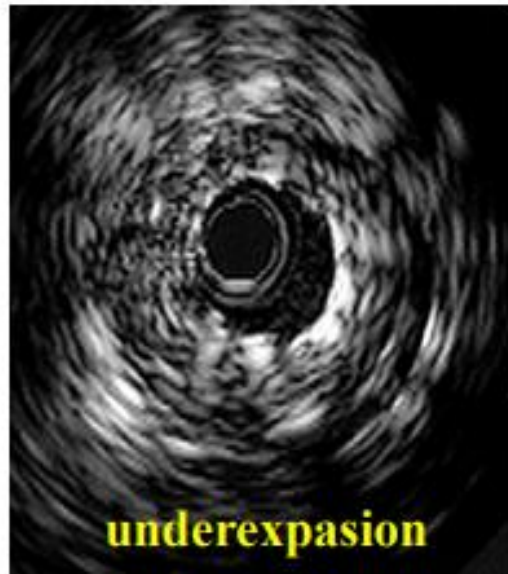
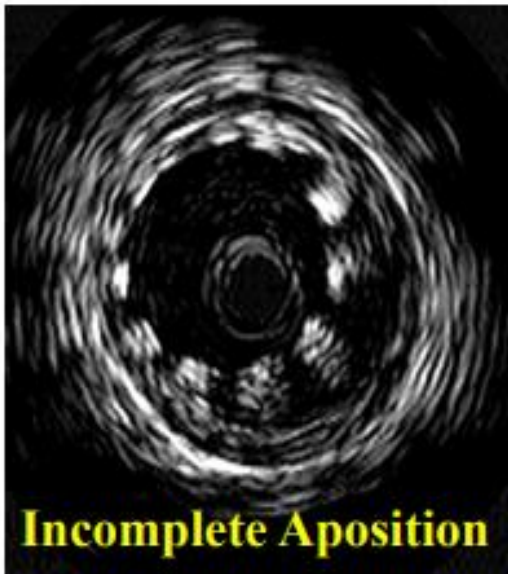
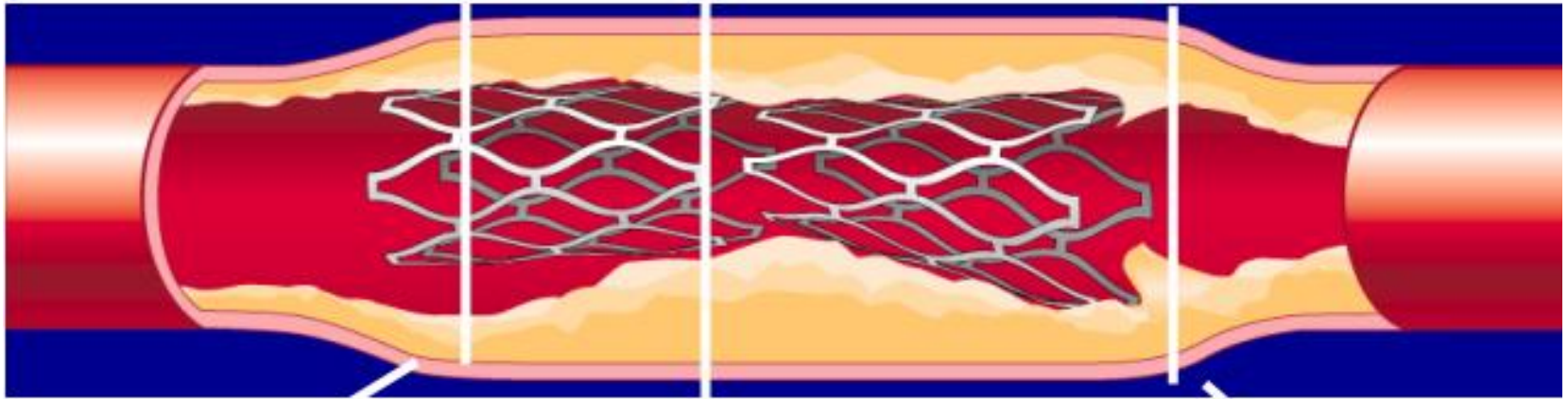
OU

- AMS $\geq 80\%$ da área média do lúmen de referência ou $\geq 90\%$ do segmento de referência com a área mais baixa quando o AMS é $\geq 9 \text{ mm}^2$
- Expansão simétrica do stent definida pelo diâmetro mínimo do lúmen dividido pelo diâmetro máximo do lúmen $\geq 0,7$

Avaliação de Falência dos Stents (Reestenose/Trombose) – Expansão NEOATEROSCLEROSE = OCT

| Causes of Stent Failure | | | | | | | | | |
|--|-------------------|------|------------|-----|---------------------|----------|------|------------|------|
| | Bare Metal Stents | | | | Drug-eluting Stents | | | | |
| | ST | | Restenosis | | ST | | | Restenosis | |
| | <30d | >1y | <5y | >5y | <30d | 30d - 1y | >1y | <18m | >18m |
| Intimal hyperplasia | | | IVUS | | | | | IVUS | |
| Procedure-related complications incl. underexpansion | IVUS | | IVUS | | IVUS | | | IVUS | |
| Late malapposition or aneurysm | | | | | | | IVUS | | |
| Erosion | | | | | | | x | | |
| Vessel wall inflammation | | | | | | | x | | |
| Stent fracture | IVUS | IVUS | | | IVUS | | IVUS | | IVUS |
| Delayed healing | | | | | | x | | | |
| Uncovered stent struts/fibrin deposition | | | | | | x | x | | |
| Neoatherosclerosis | | x | | x | | | x | | x |

Mecanismo Reestenose



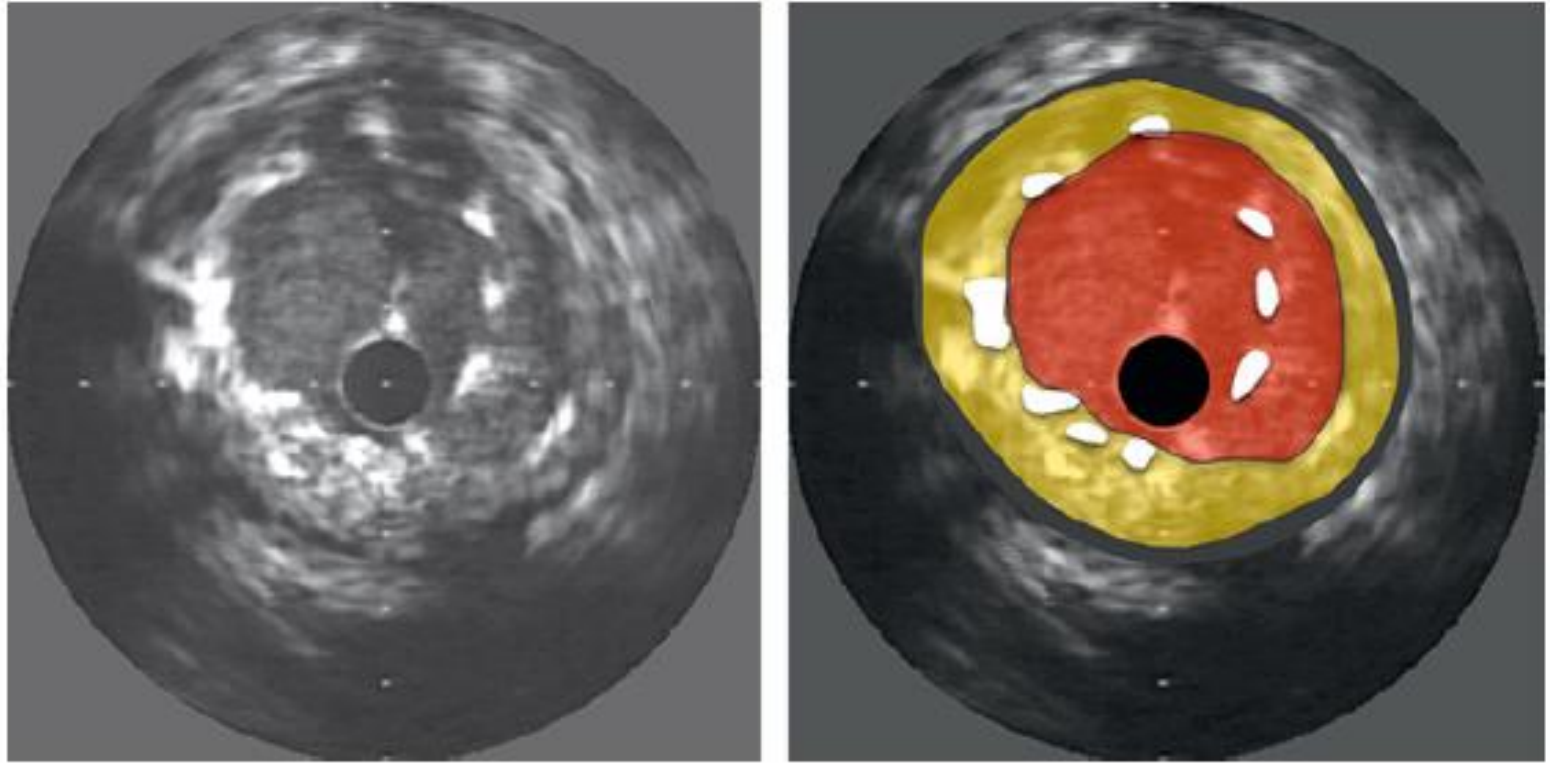


Figure 4 Intravascular ultrasound cross-section at a site with unopposed coronary stent struts.

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 | |

2014 ESC/EACTS Guidelines on myocardial revascularization

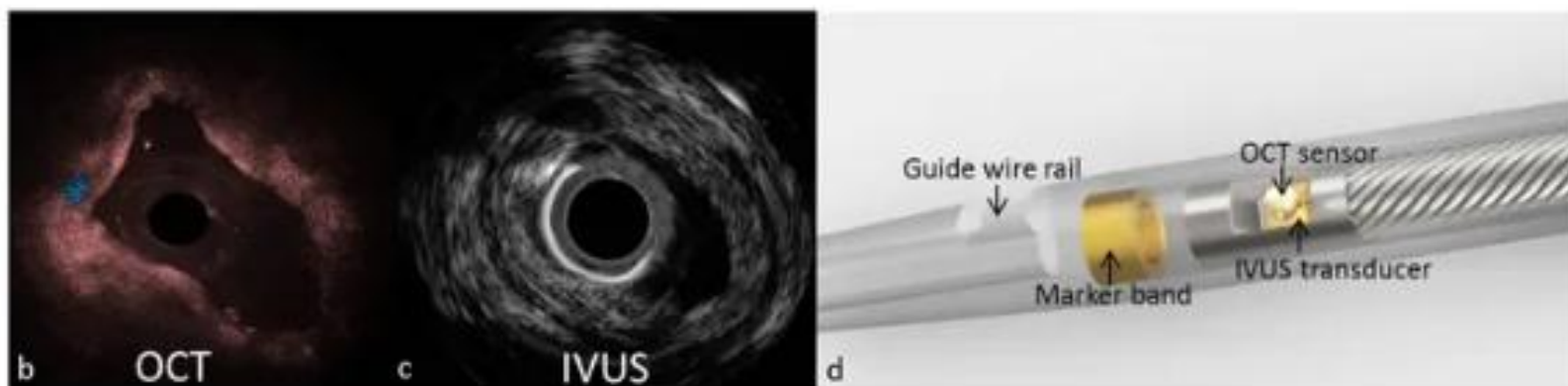
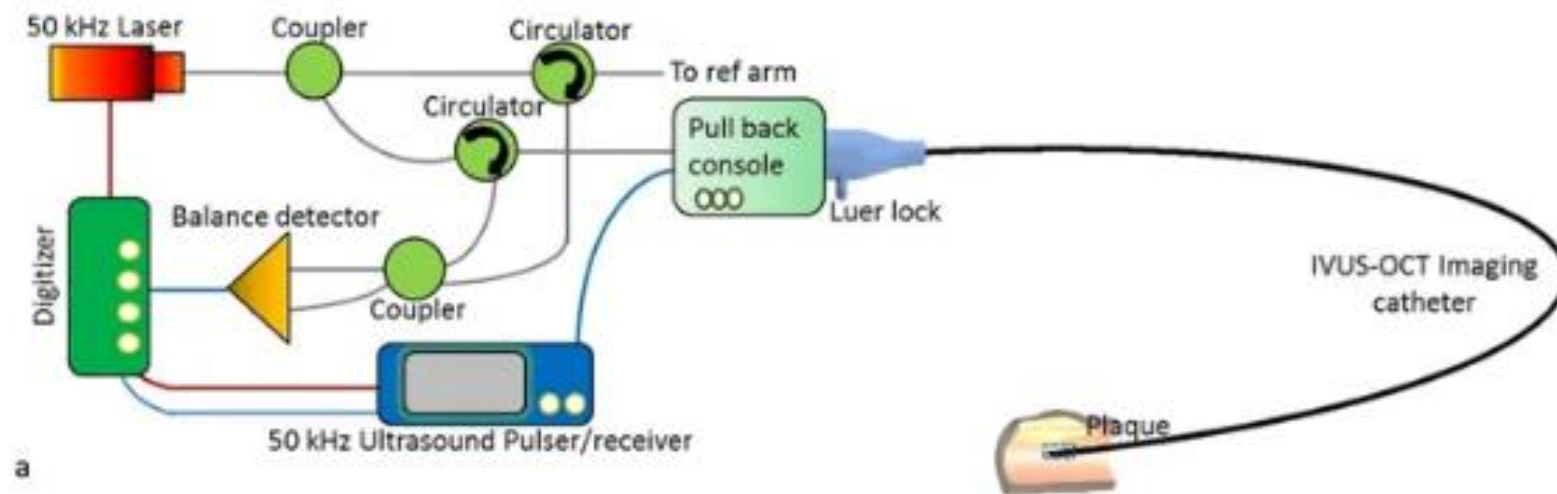
The Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS)

DIRETRIZ

| Recomendações | Classe | Nível de evidência | Referências |
|--|--------|--------------------|---|
| A USIC pode ser utilizada para avaliar lesões intermediárias/ambíguas em TCE e para guiar seu tratamento | Ila | B | Abizaid et al. ³⁴¹ de la Torre Hernandez et al. ³⁴² Jasti et al. ³⁴³ Park et al. ⁶³⁵ |
| A USIC pode ser utilizada, em casos selecionados, para guiar implante de stents coronários | Ila | B | Casella et al. ⁶³⁶ Chieffo et al. ⁶³⁷ Parise et al. ⁶³⁸ Witzenbichler et al. ⁶³⁹ Zhang et al. ⁶⁴⁰ Ahn et al. ⁶⁴¹ |
| A USIC pode ser utilizada para determinar o mecanismo de falência dos stents (reestenose e trombose), auxiliando na decisão sobre a melhor terapêutica a ser instituída | Ila | C | |
| A USIC pode ser utilizada para avaliar precocemente (entre 4 semanas e 12 meses) a presença de doença vascular do enxerto em pacientes submetidos a transplante cardíaco, inclusive fornecendo informações com valor prognóstico | Ila | B | Kobashigawa et al. ⁶⁴² Kapadia et al. ⁶⁴³ |
| A USIC pode ser utilizada para avaliar lesões intermediárias (40-70%) em coronárias nativas, à exceção do TCE | IIb | B | Waksman et al. ⁶³¹ |

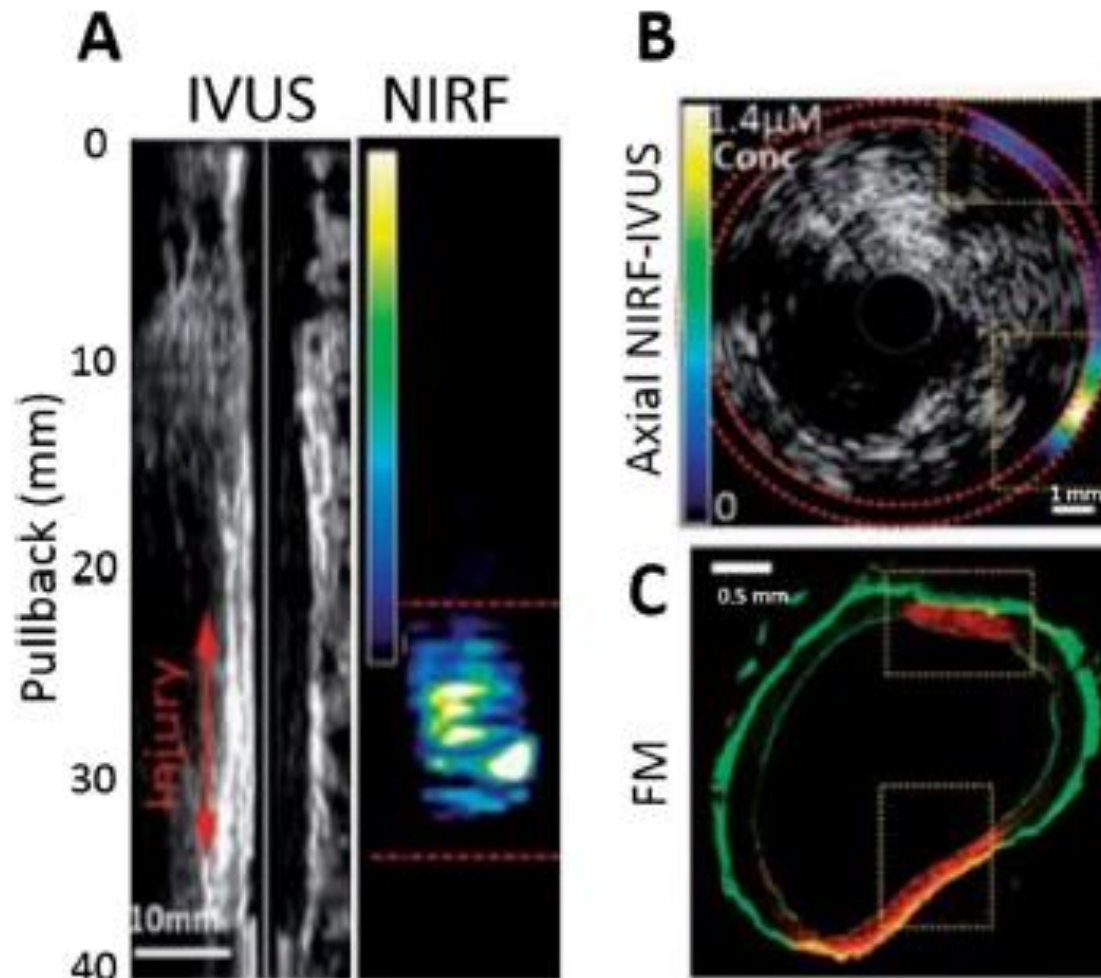
TCE: tronco de coronária esquerda; USIC: ultrassonografia intracoronária.

Figure 1



Ultrafast IVUS-OCT imaging system and catheter.

Imagem Intravascular Molecular usando Fluorescência no Infravermelho próximo (NIRF)



"TAKE HOME MESSAGE"

- *Em alguns casos, a cine isolada não é capaz de nos dar a resposta adequada para a correta tomada de decisão – "Top 5s".*
- *A determinação de fatores anatômicos relacionados ao vaso-alvo durante sua intervenção parece ser óbvia, mas é crucial para a otimização dos resultados.*

"TAKE HOME MESSAGE"

- *Perde-se muito tempo e energia na escolha do diâmetro x comprimento do stent*
- *Deve-se perder muito mais tempo e muito mais energia na **otimização dos resultados** da angioplastia coronariana.*

Referências

- Gülel et al. Intravascular ultrasound: questions and answers.
- Hassan et al. Current Use of Intravascular Ultrasound in Coronary Artery Disease.
- Räber et al. Clinical use of intracoronary imaging. Part 1: guidance and optimization of coronary interventions. An expert consensus document of the European Association of Percutaneous Cardiovascular Interventions.

OBRIGADO!!

A História tem demonstrado que os mais notáveis vencedores normalmente encontraram obstáculos dolorosos antes de triunfarem. Eles venceram porque se recusaram a se tornarem desencorajados por suas derrotas.

Bryan Forbes