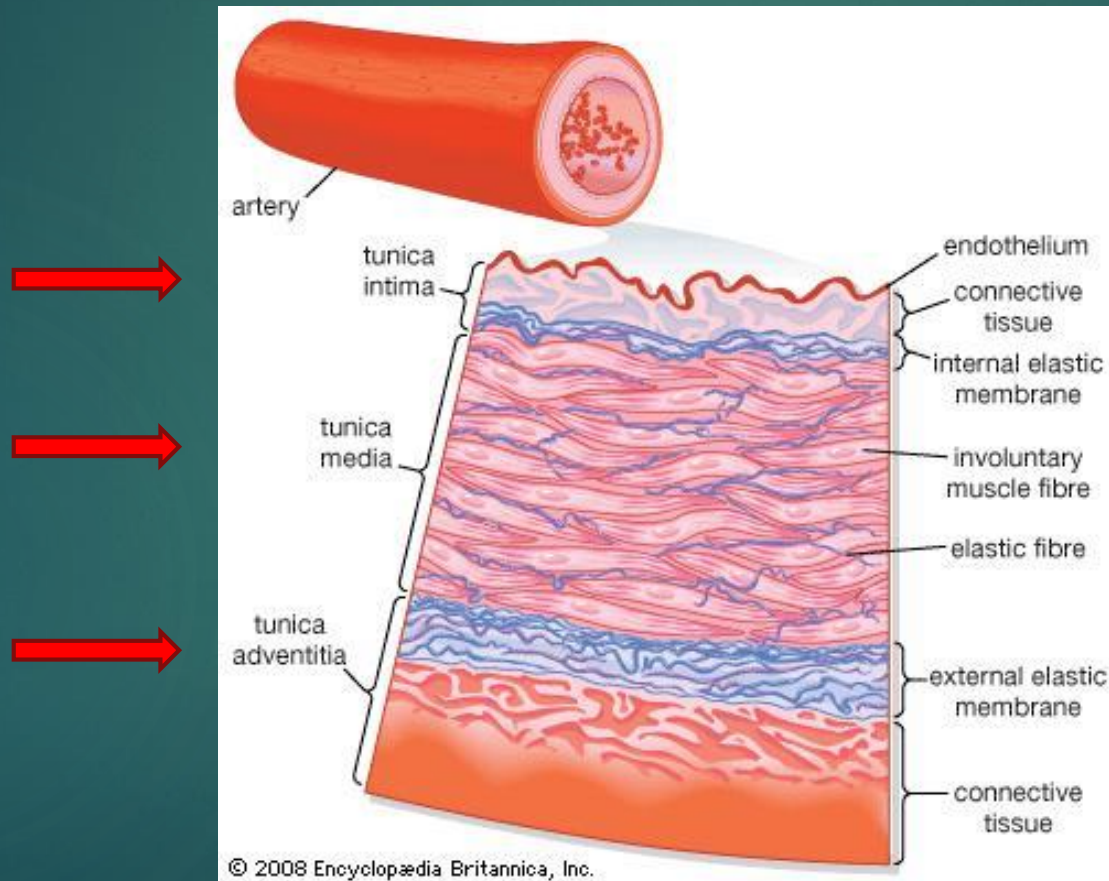




IVUS, FFR and iFR

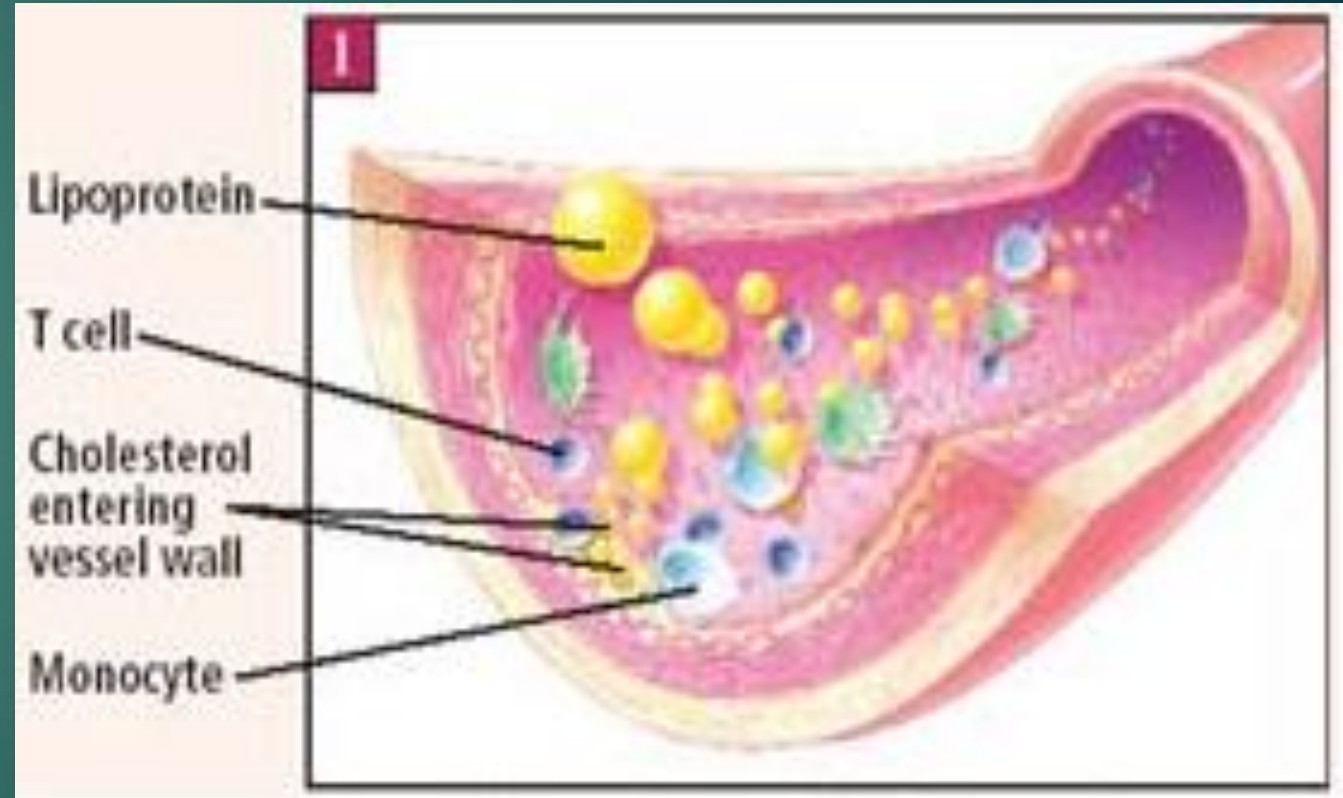
WHAT IS IT AND WHY DO WE USE IT?

First, basic arterial anatomy and physiology



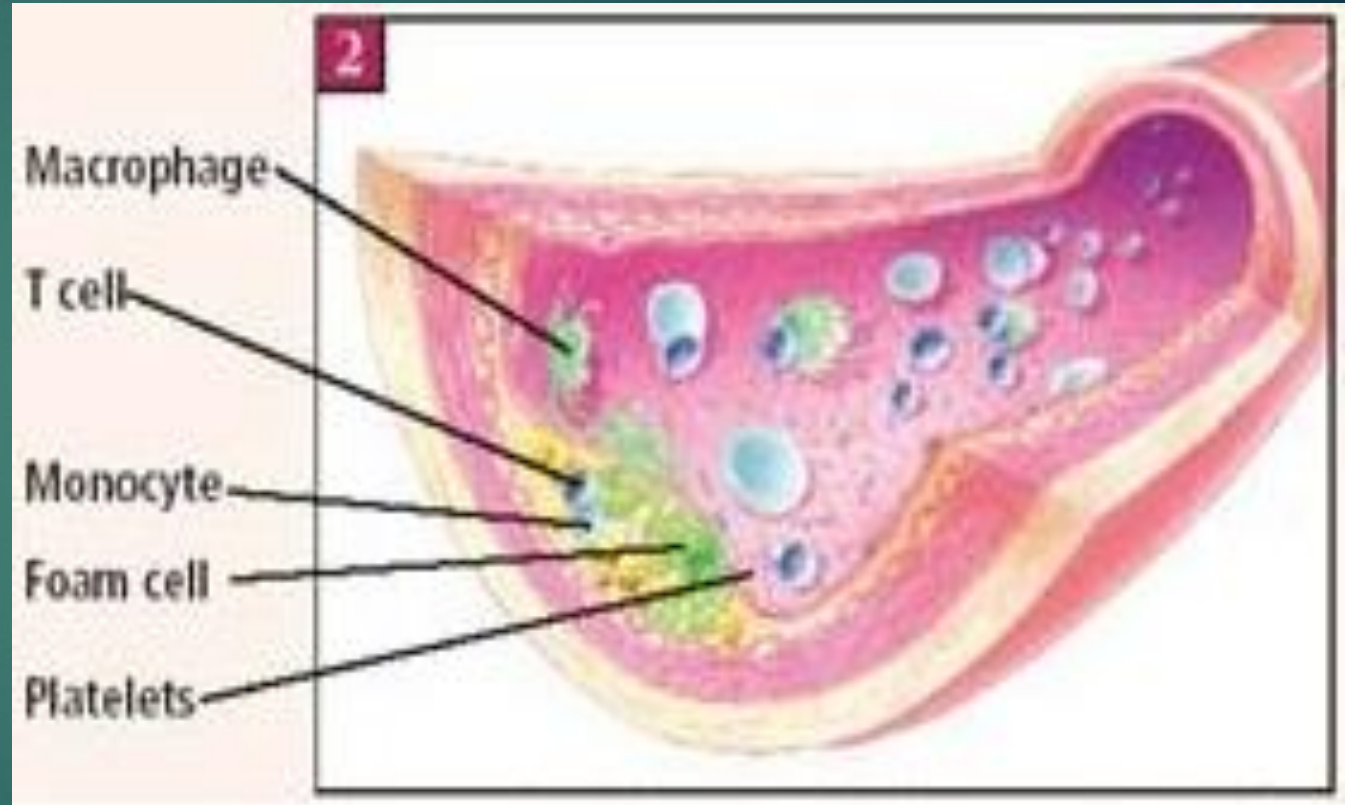
Atherosclerosis, an inflammatory process

- Lipoprotein deposition.



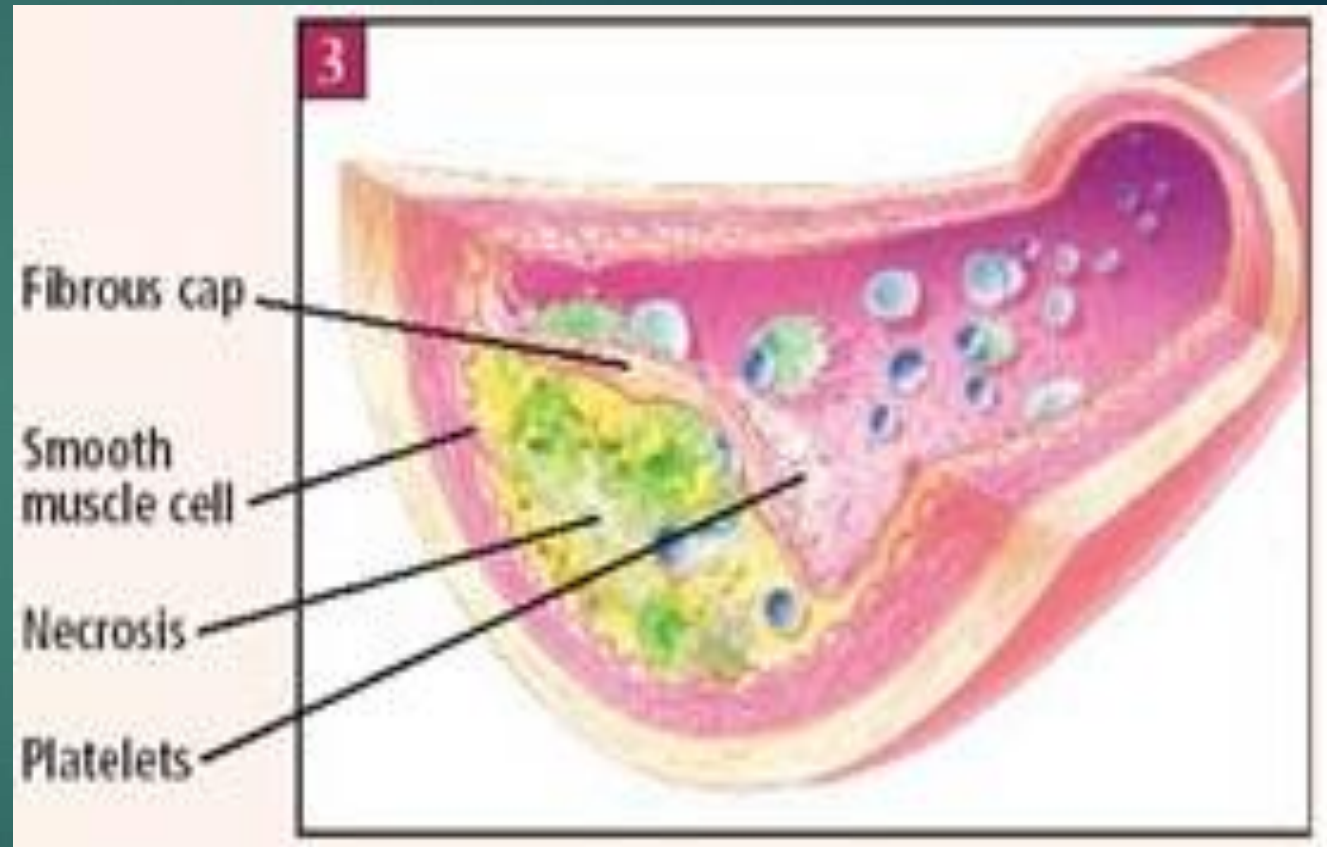
Atherosclerosis, an inflammatory process

- Foam cell creation.



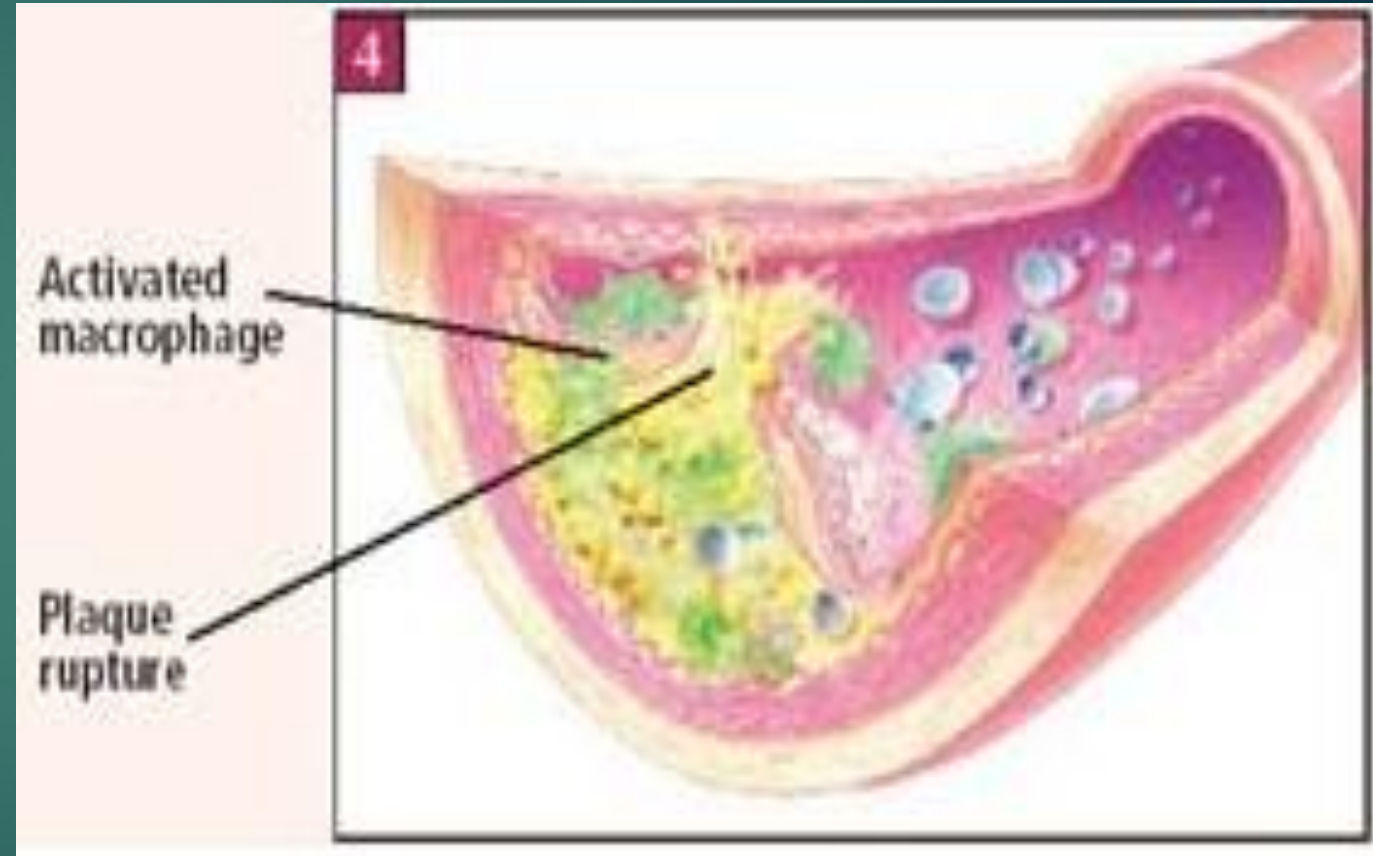
Atherosclerosis, an inflammatory process

- Platelet aggregation.
- Responsibility of smooth muscle cells.



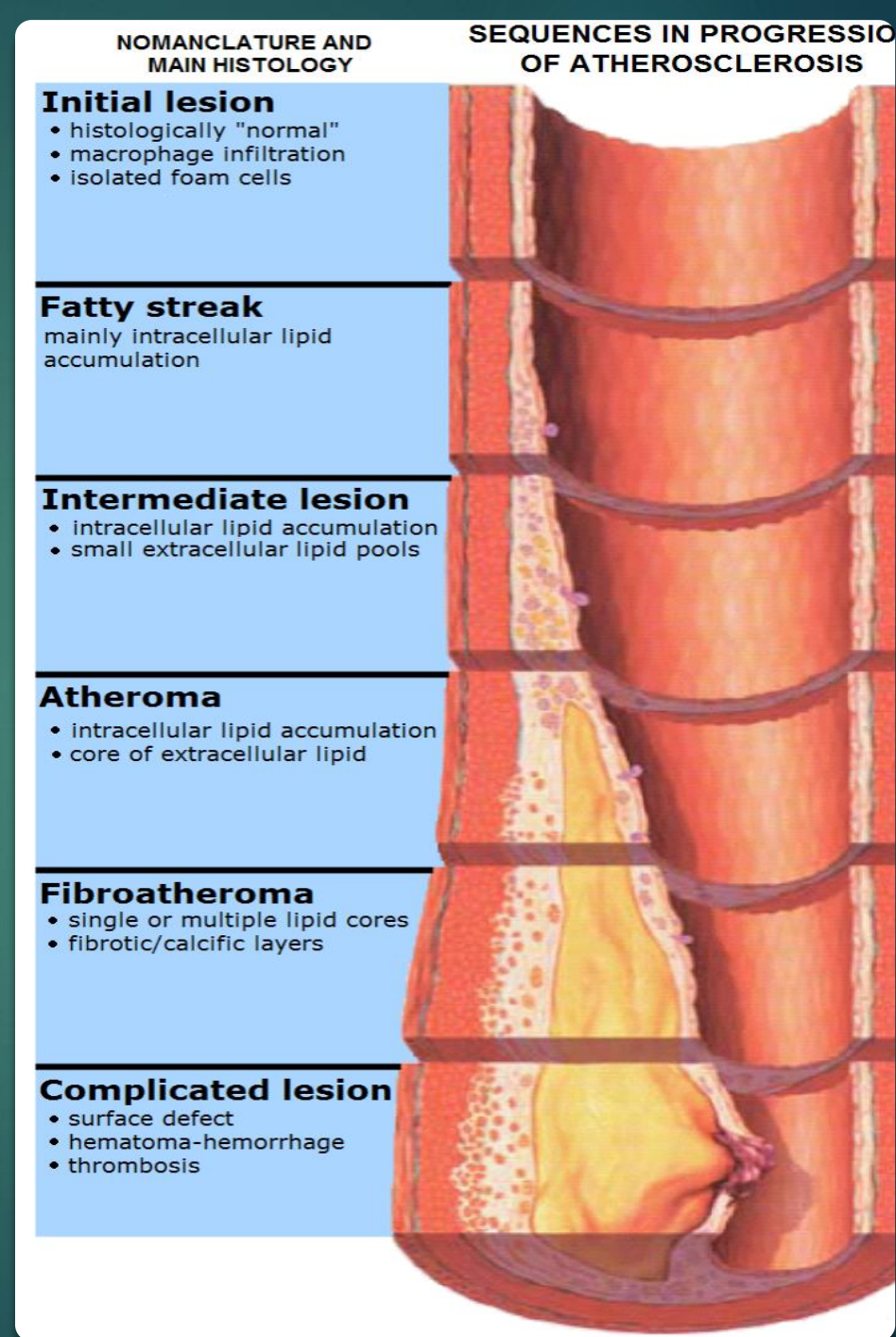
Atherosclerosis, an inflammatory process

- Plaque rupture and Thrombosis.



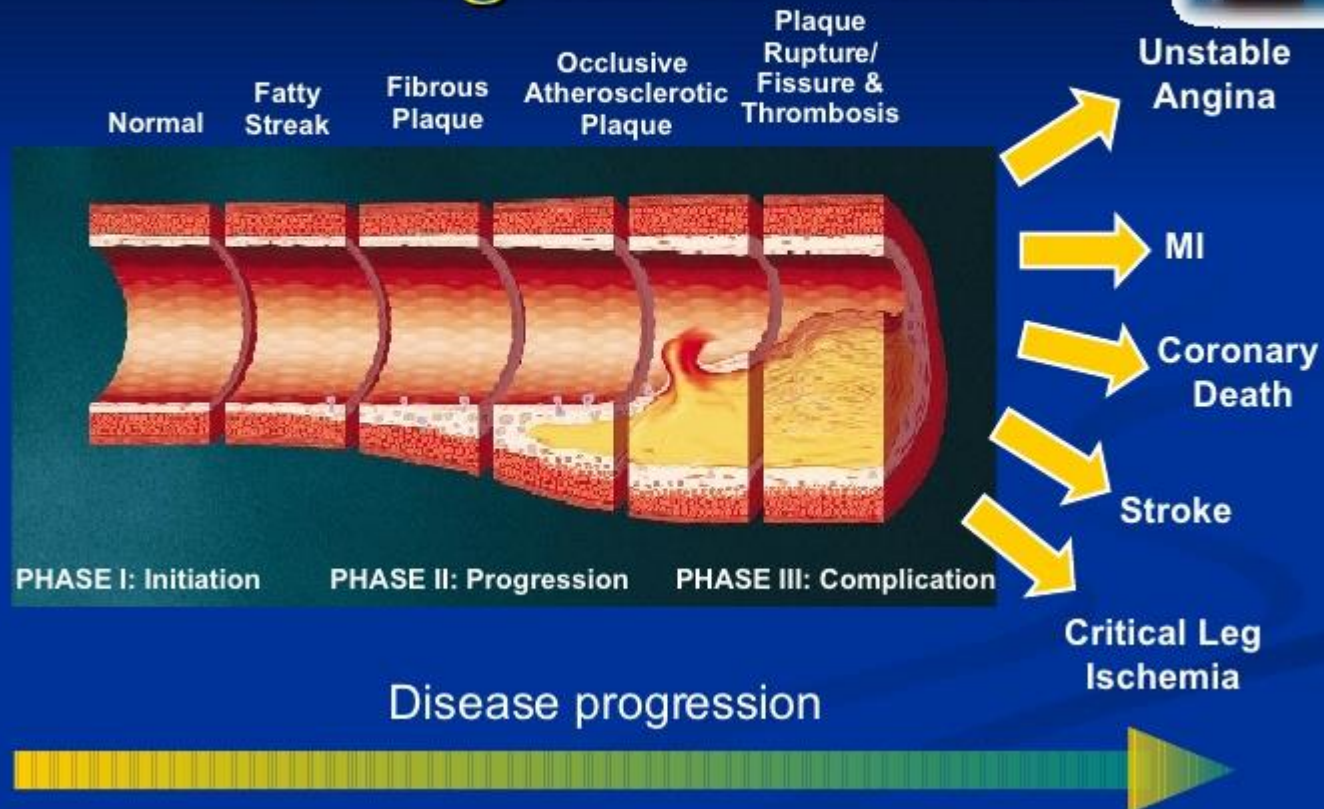
Atherosclerosis, an inflammatory process

- Timescale of plaque formation.

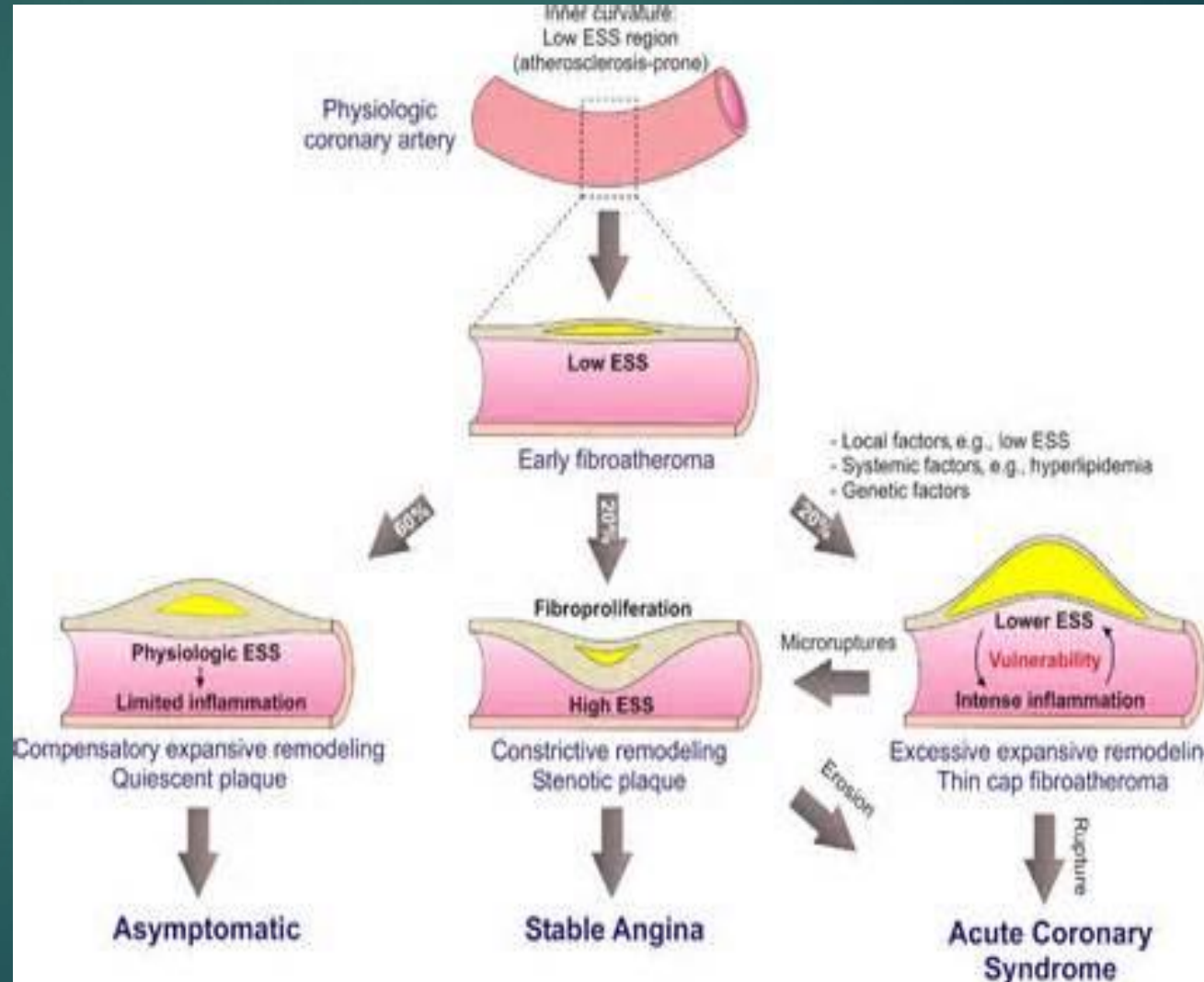
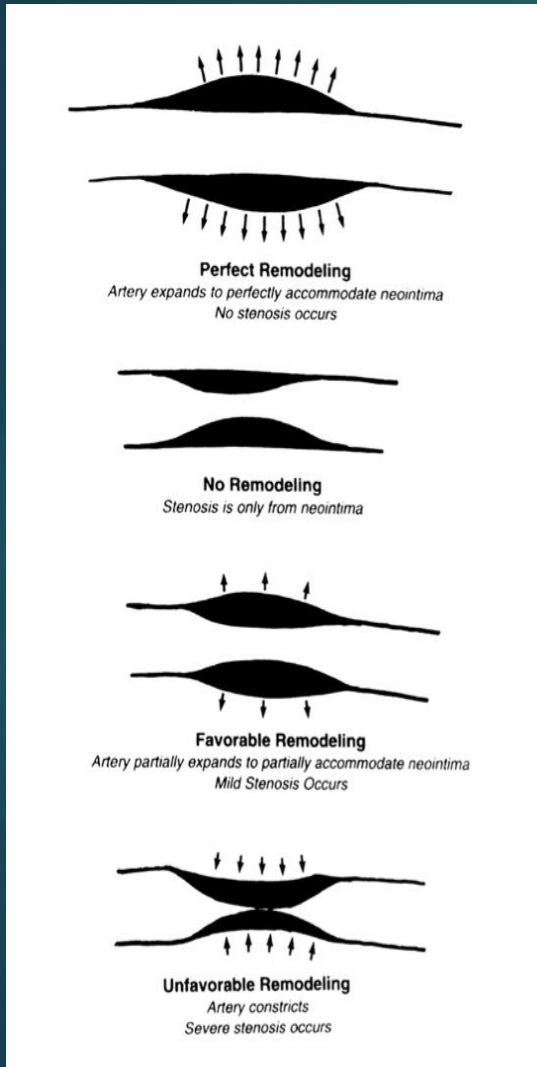


Vascular Remodeling

Atherosclerosis: A Progressive Process

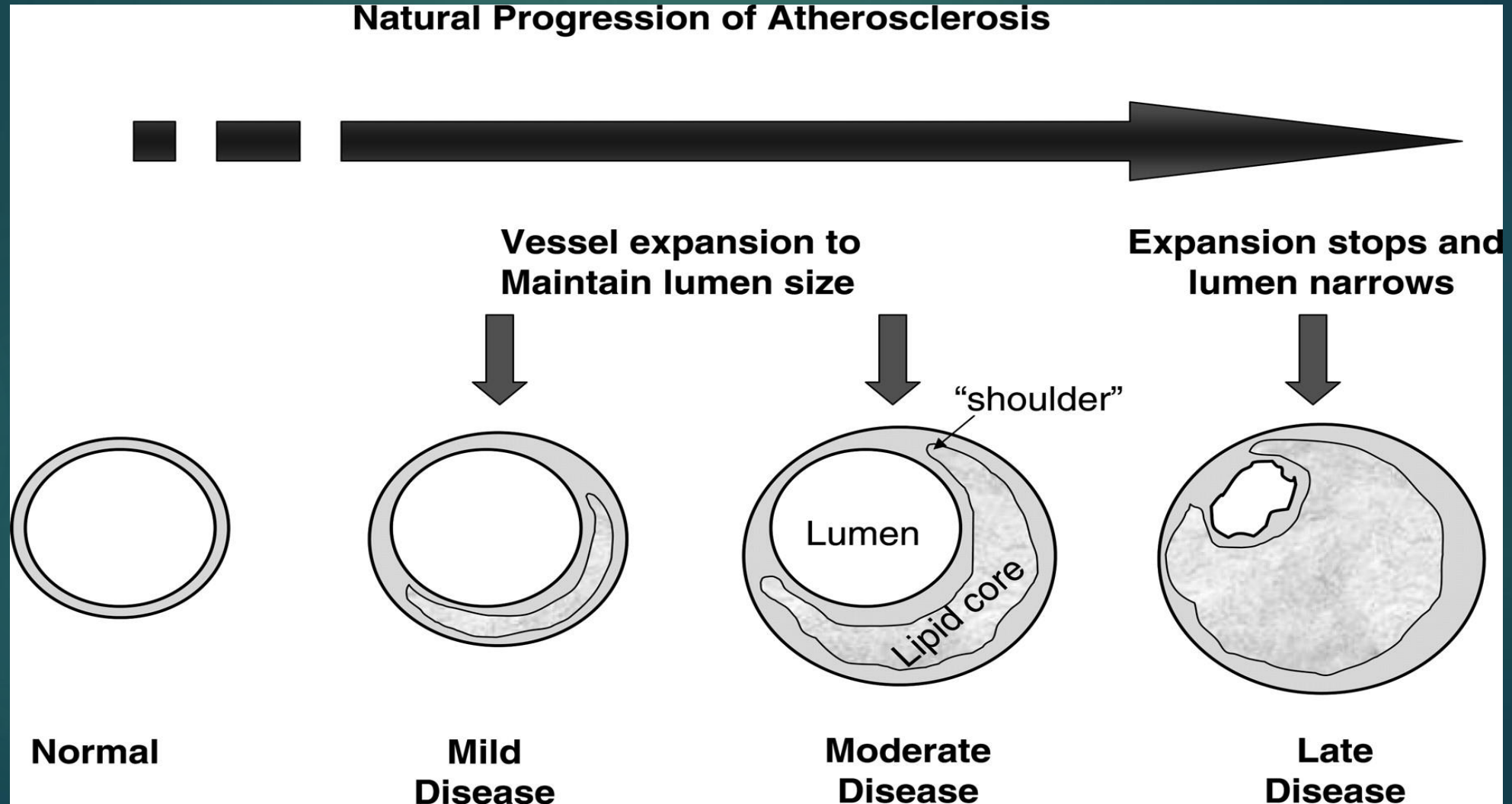


Vascular Remodeling

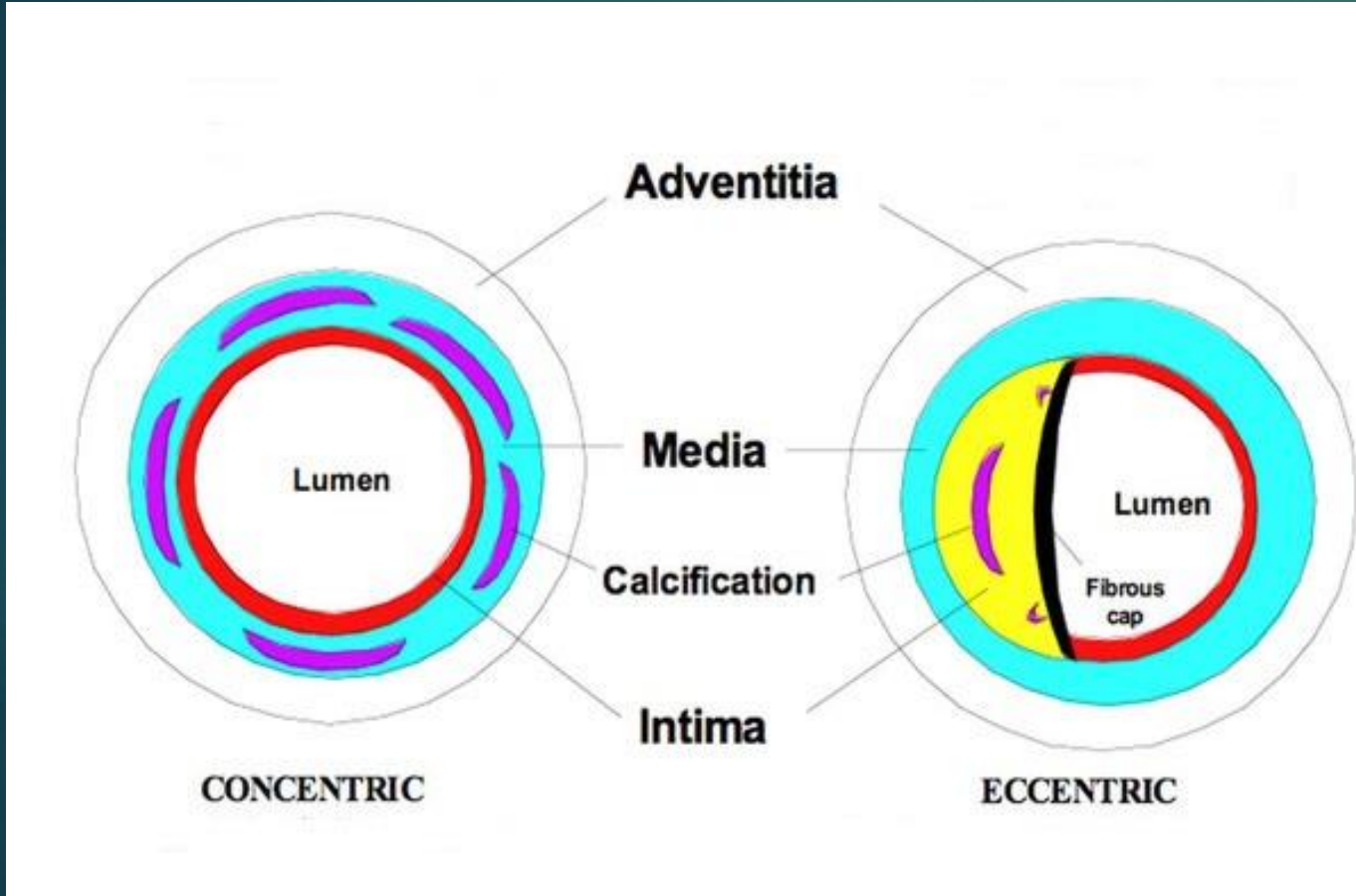


ESS = Endothelial Shear Stress

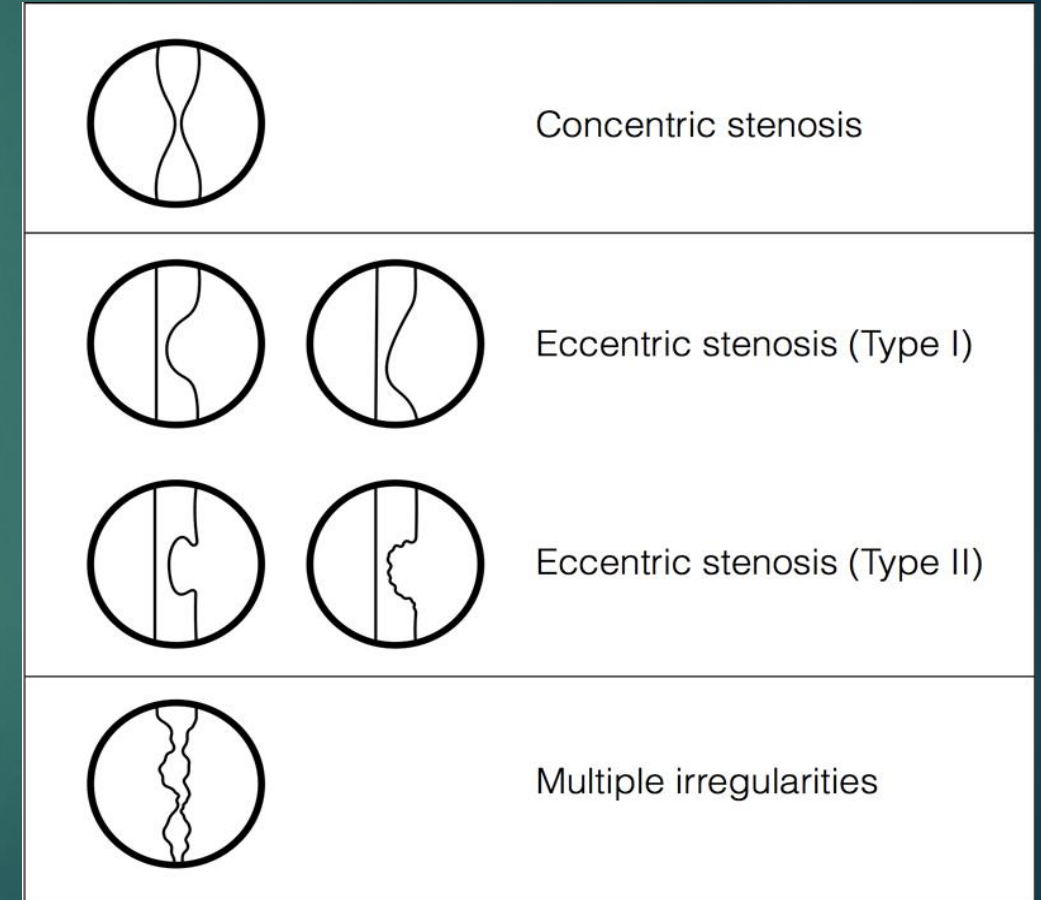
Vascular remodeling



Concentric vs Eccentric Plaques

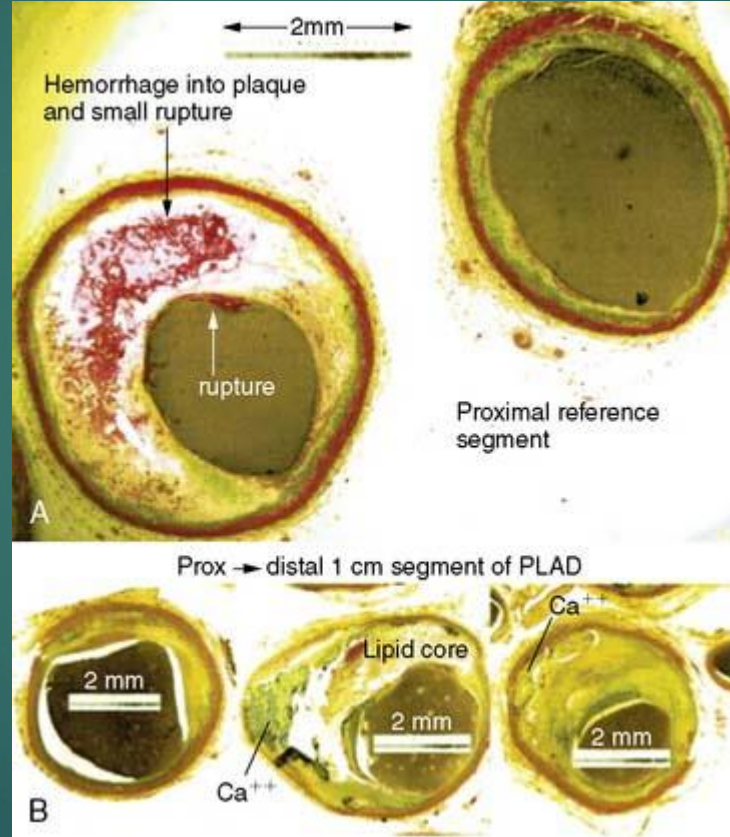
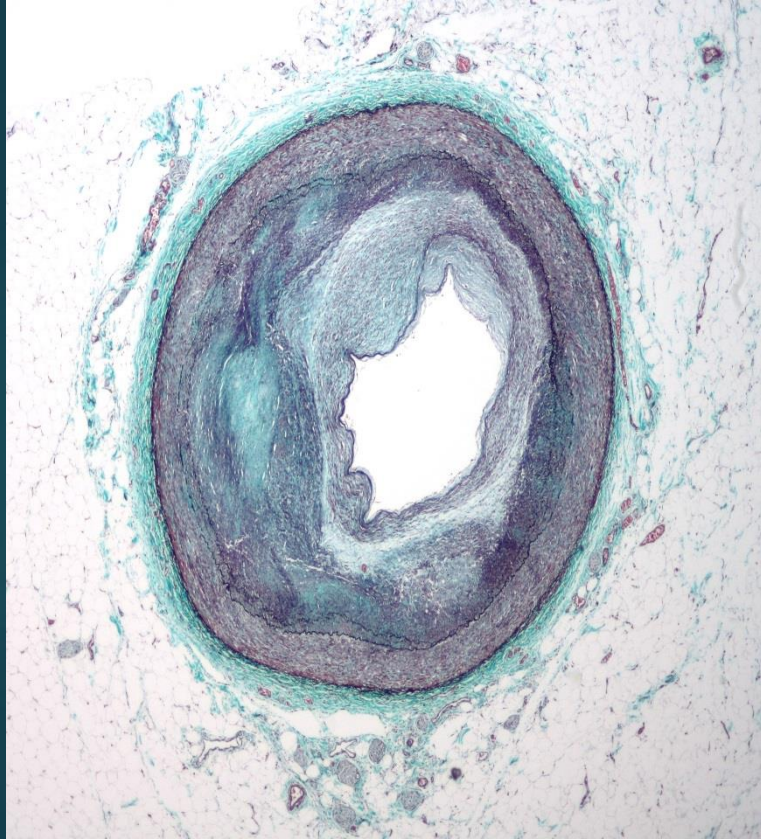


Cross-sectional view

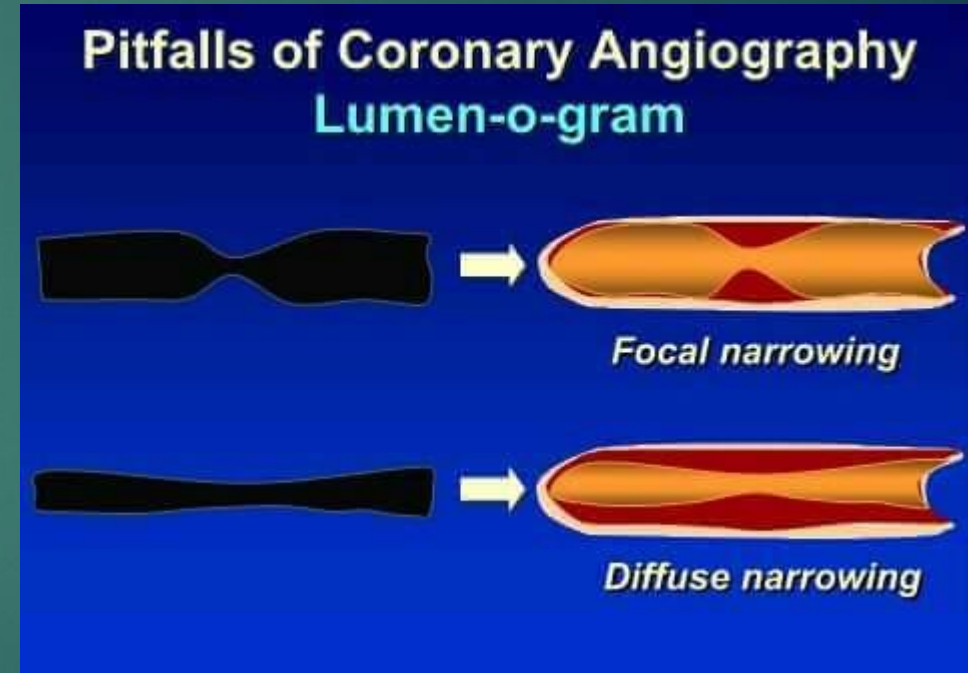
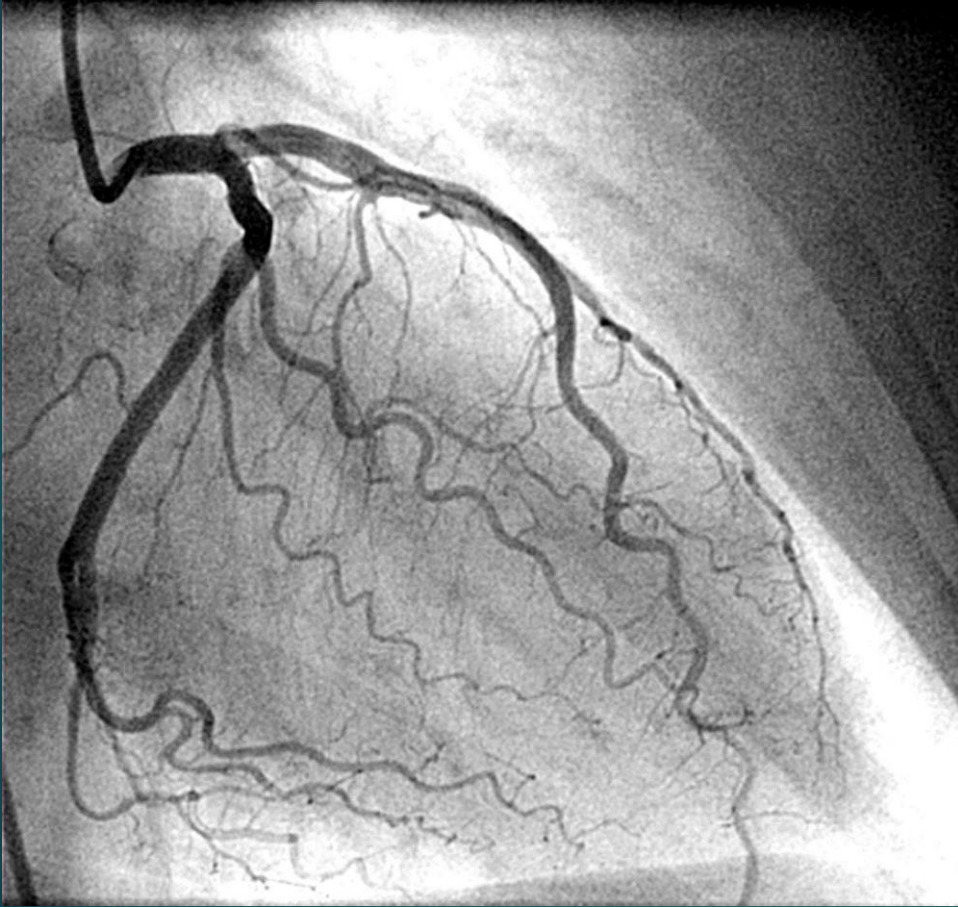


Longitudinal or Angiographic view

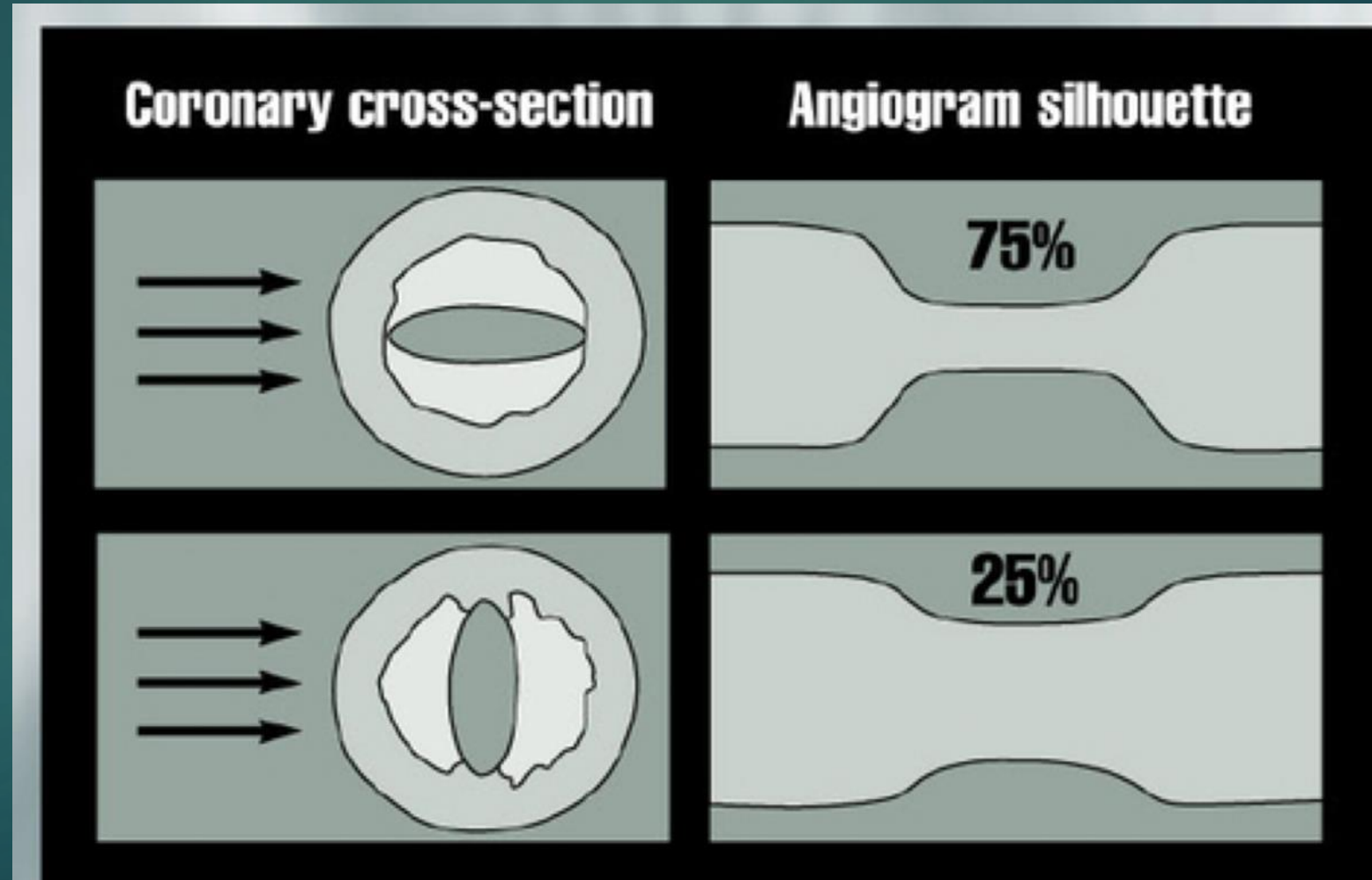
Concentric vs Eccentric Plaques



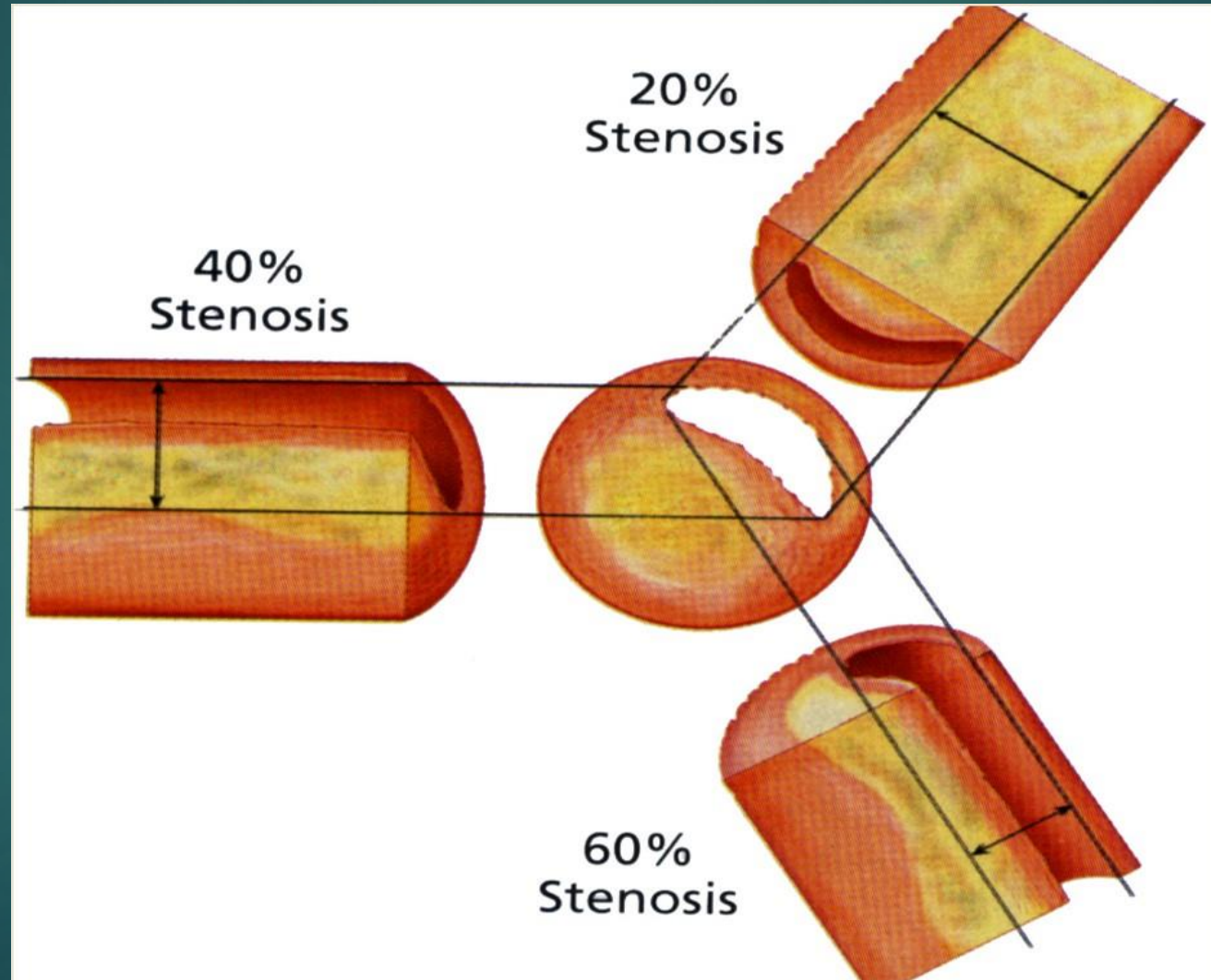
Difficulties in assessing lesion severity by angiography alone.



Difficulties in assessing lesion severity by angiography alone.



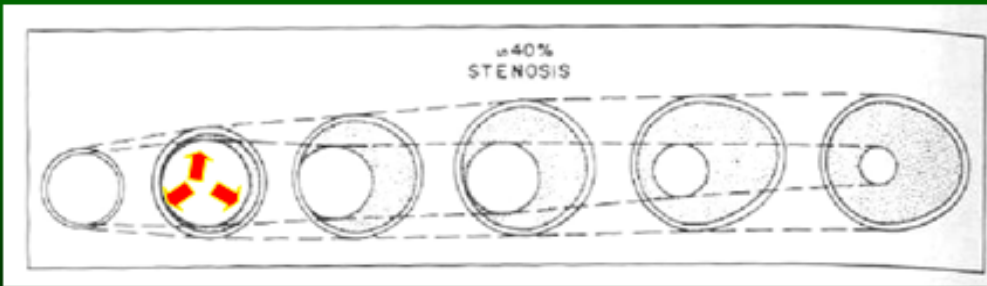
Difficulties in assessing lesion severity by angiography alone.



Difficulties in assessing lesion severity by angiography alone.



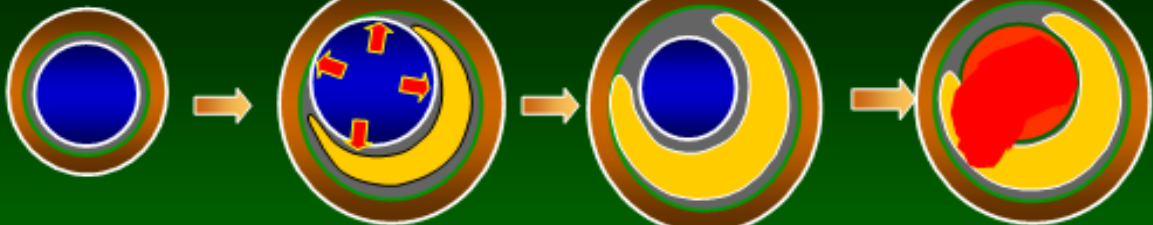
Vessel Wall Remodeling & Plaque Disruption



Early Plaque

IEL - EEL expansion

Plaque Disruption



Normal vessel

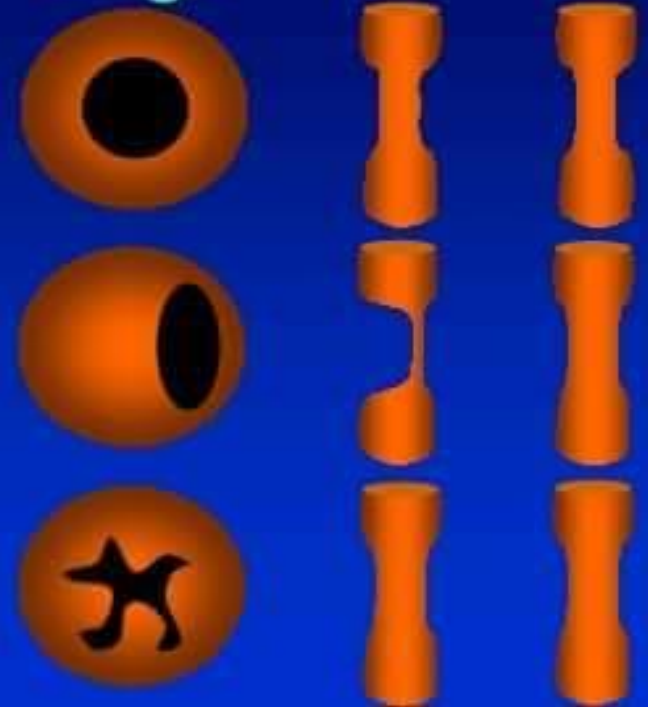
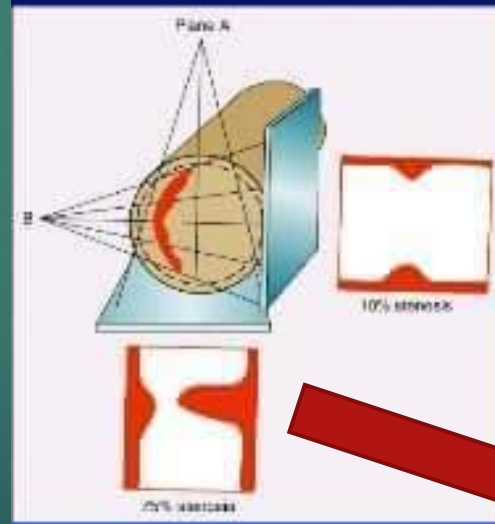
Minimal CAD

Mild to Moderate Asymptomatic CAD

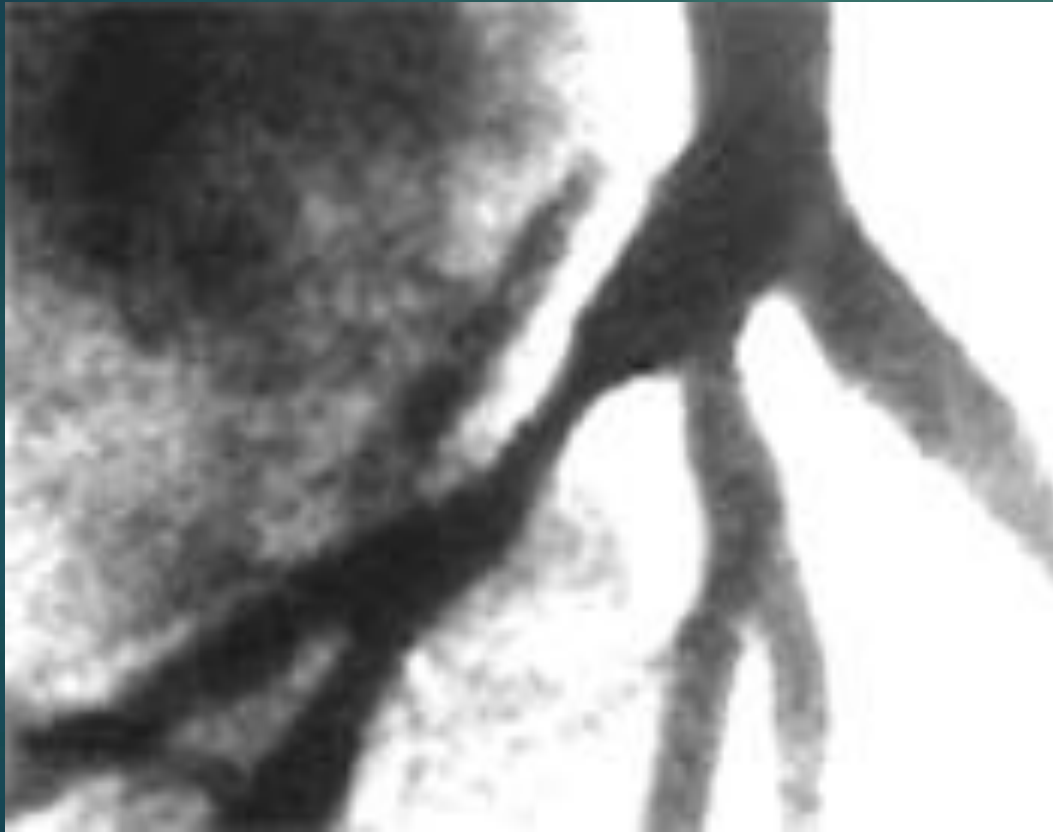
Acute CAD

Modified from Schoenhagen et al. *JACC* 2001; 38:297 and Glasgow et al. *NEJM* 1987;316:1371

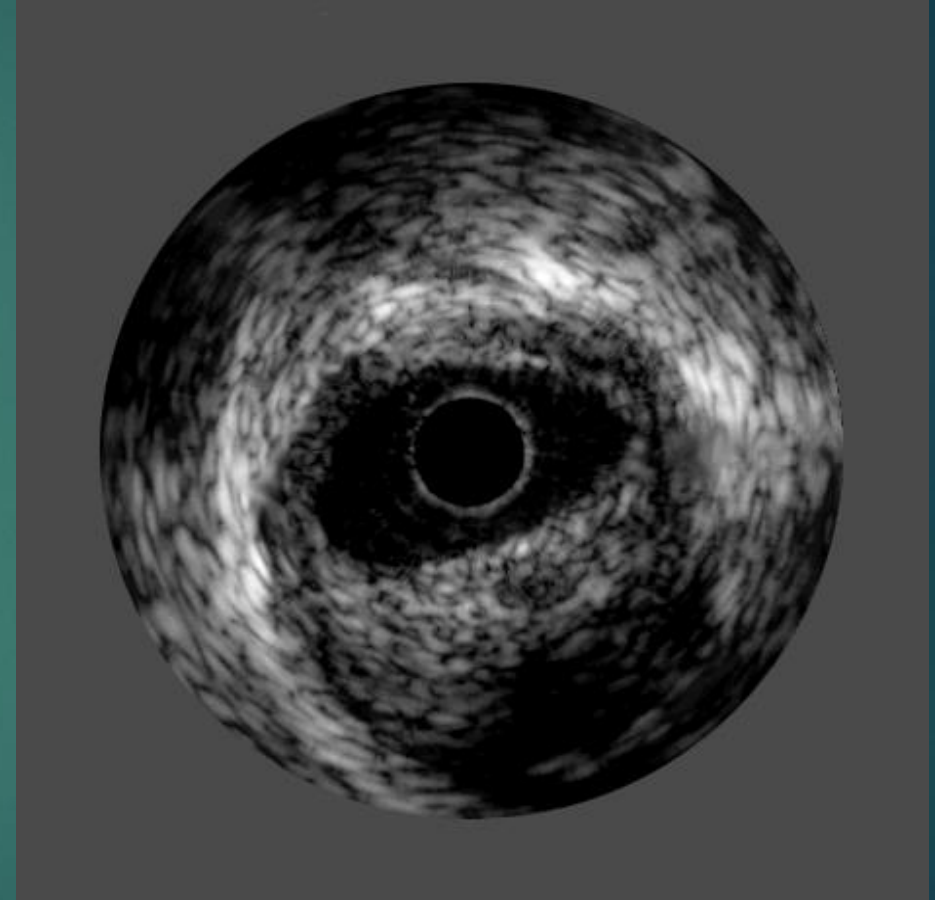
Pitfalls of Coronary Angiography Lumen-o-gram



Difficulties in assessing lesion severity by angiography alone.



IVUS Basics



IVUS Basics

IVUS stands for **I**ntra **V**ascular **U**ltra **S**ound.

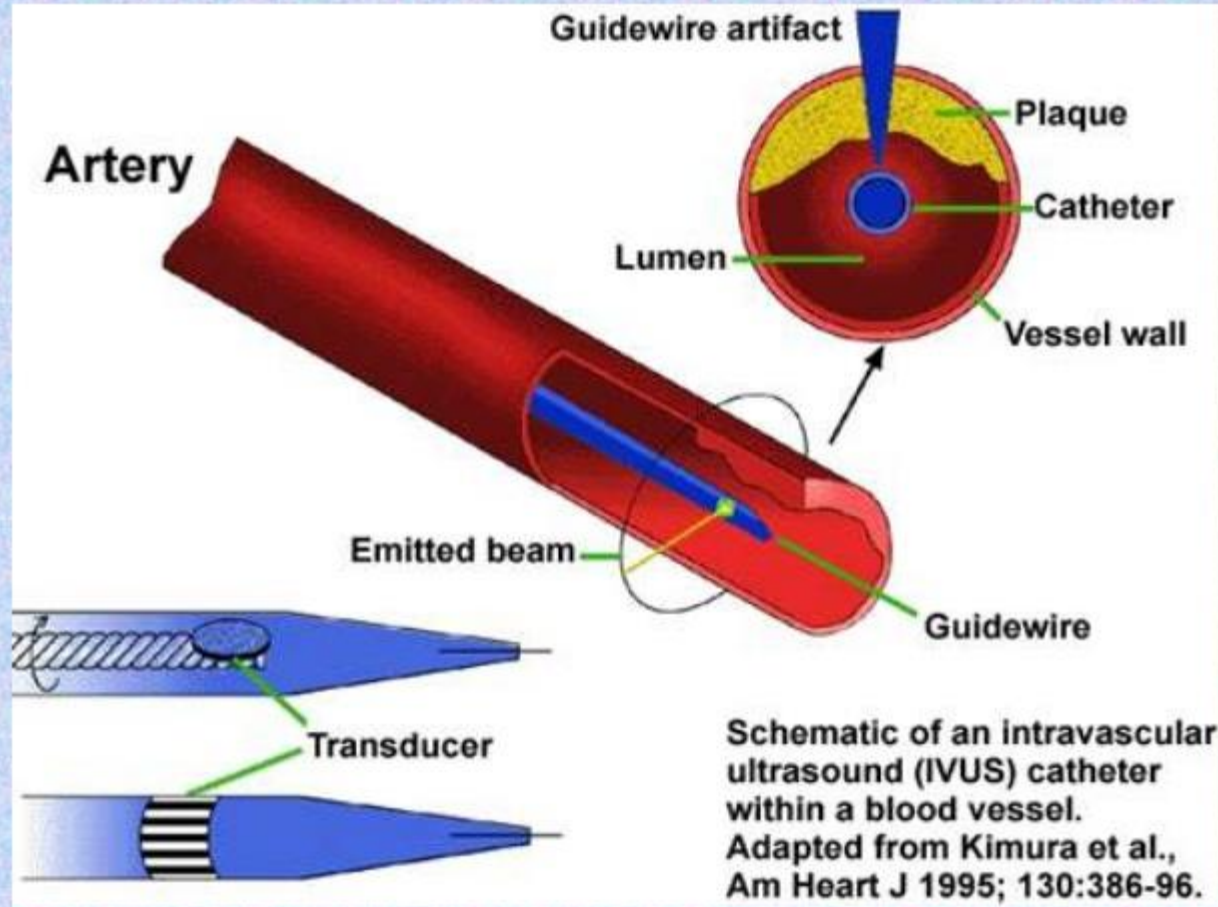
Uses ultrasound to create a tomographic image of the vasculature.

Facilitates direct measurements of the lumen dimensions.

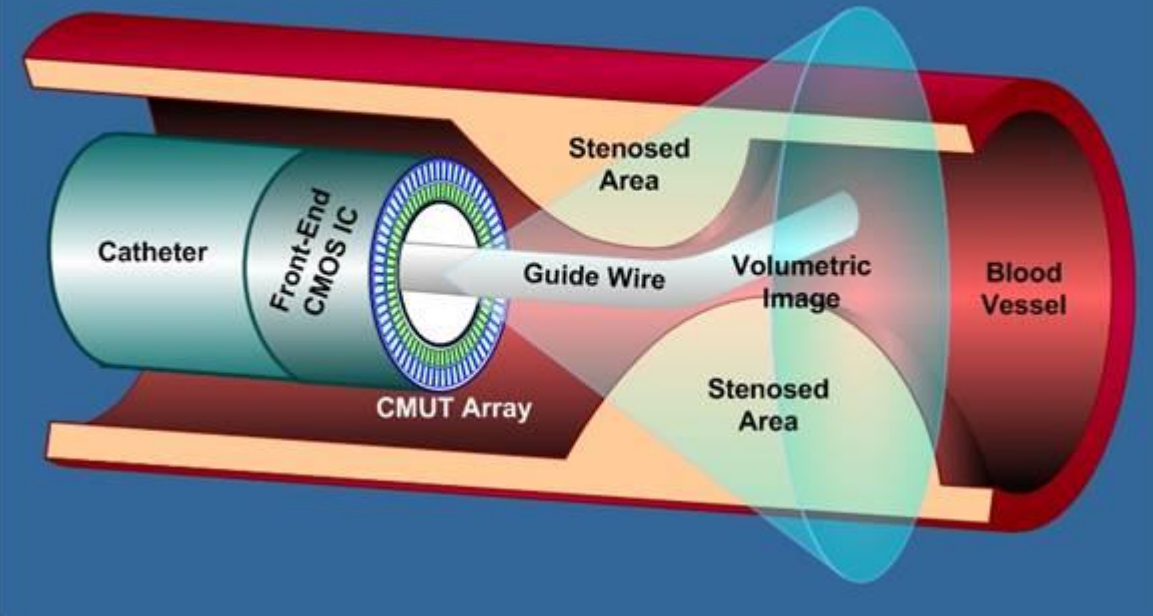
Ultrasound allows imaging of soft tissues within the arterial wall.

Allows characterization of plaque size, distribution and composition.

IVUS Basics

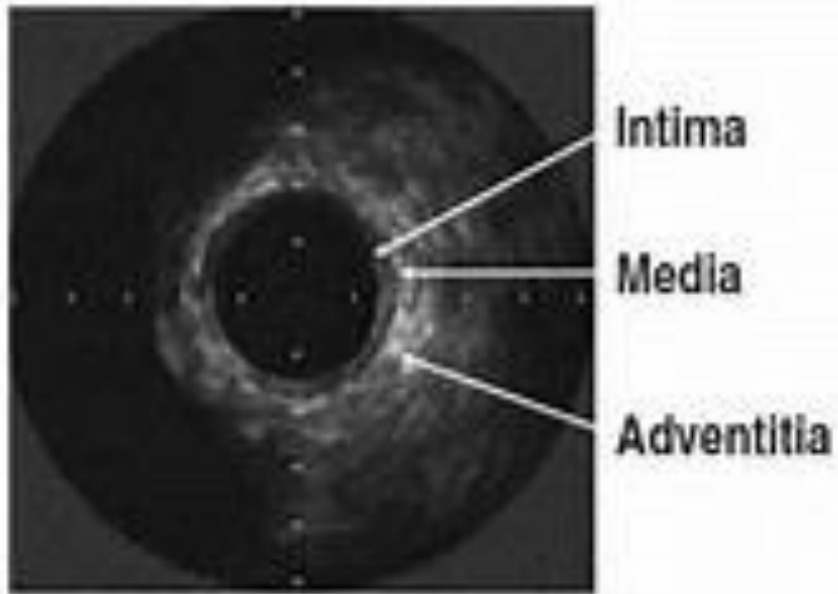


Forward-Looking IVUS Imaging Using Dual-Ring CMUT Array

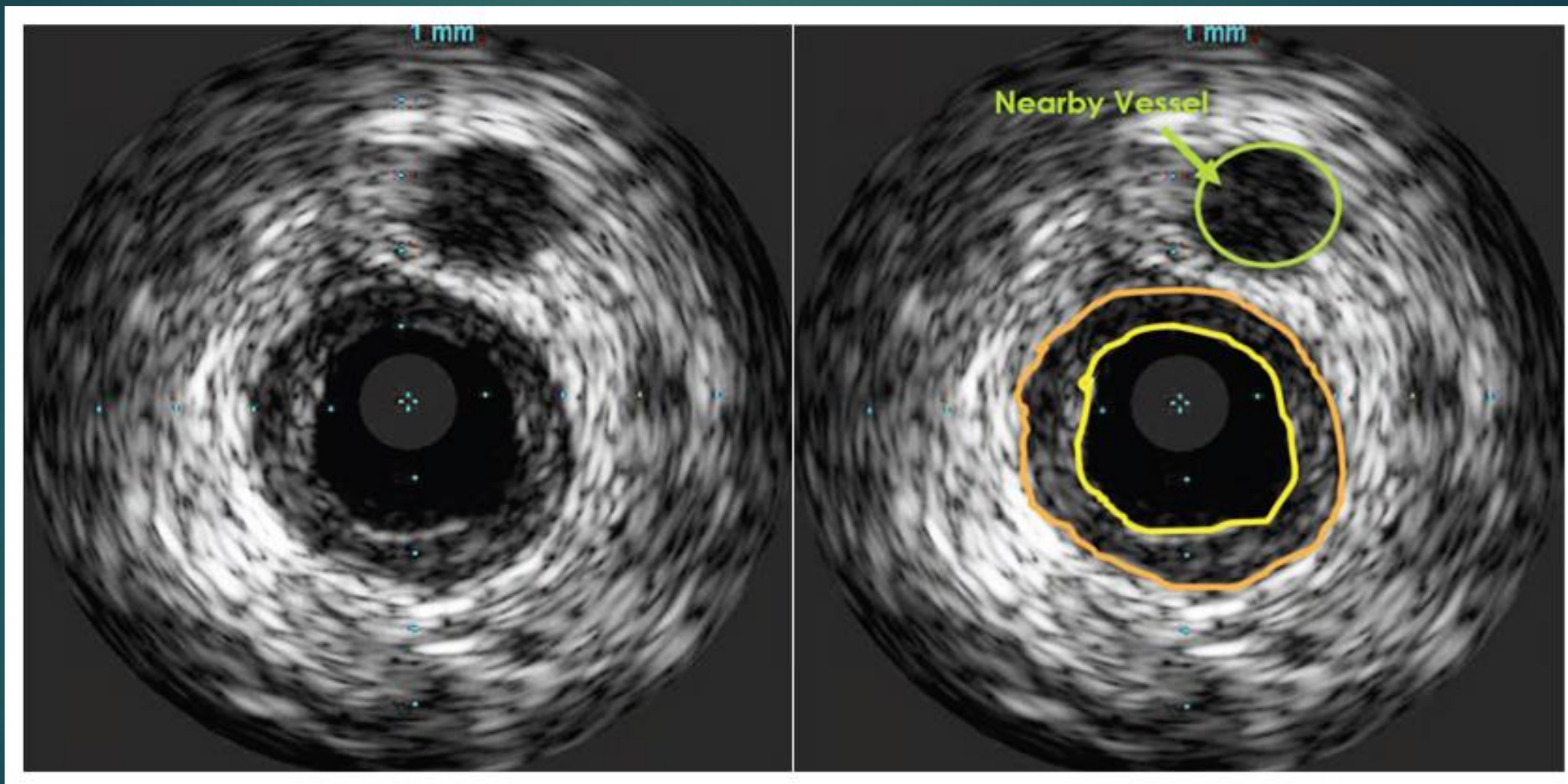


IVUS Basics

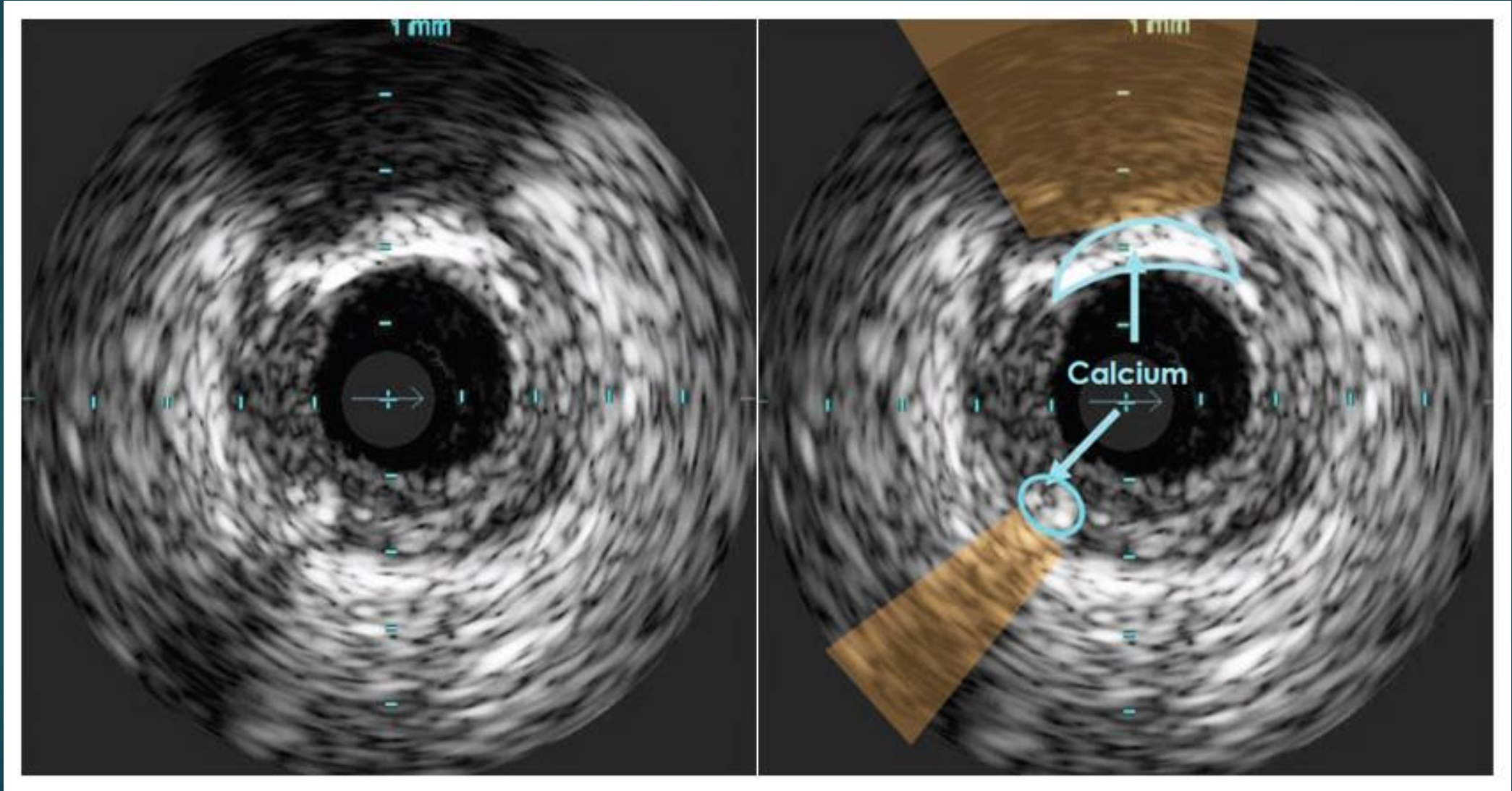
Normal Vessel



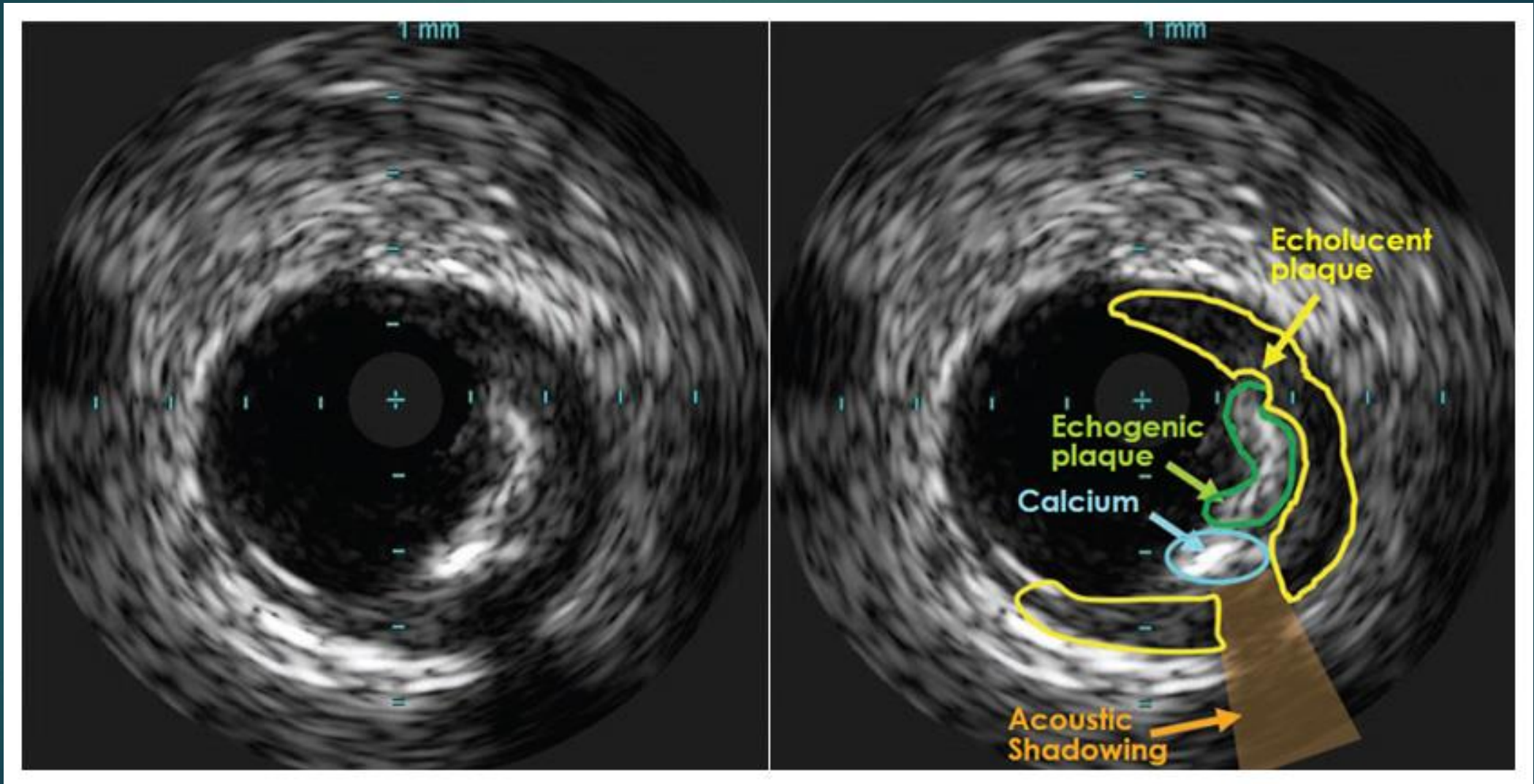
Example Images



Example Images

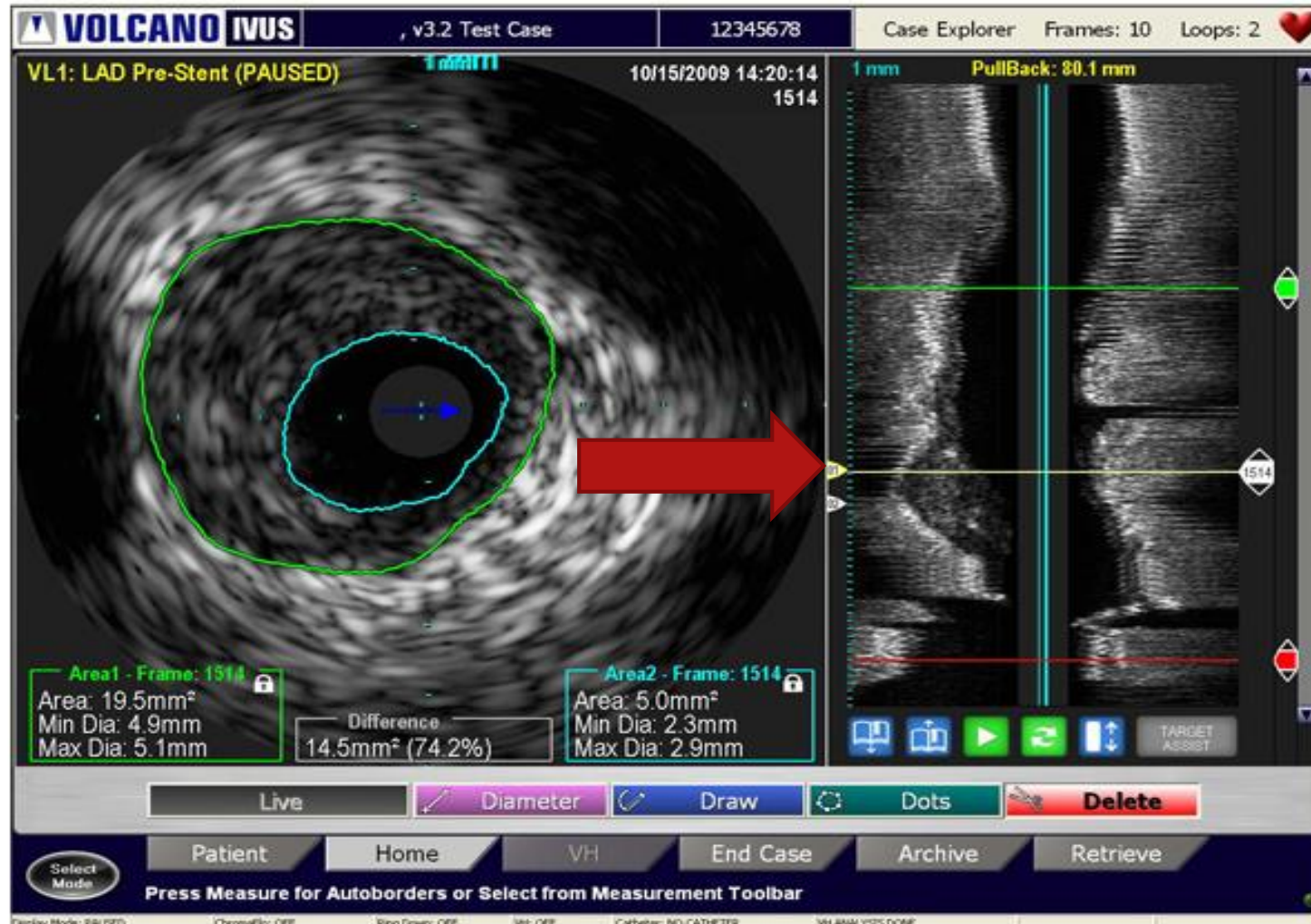


Example Images

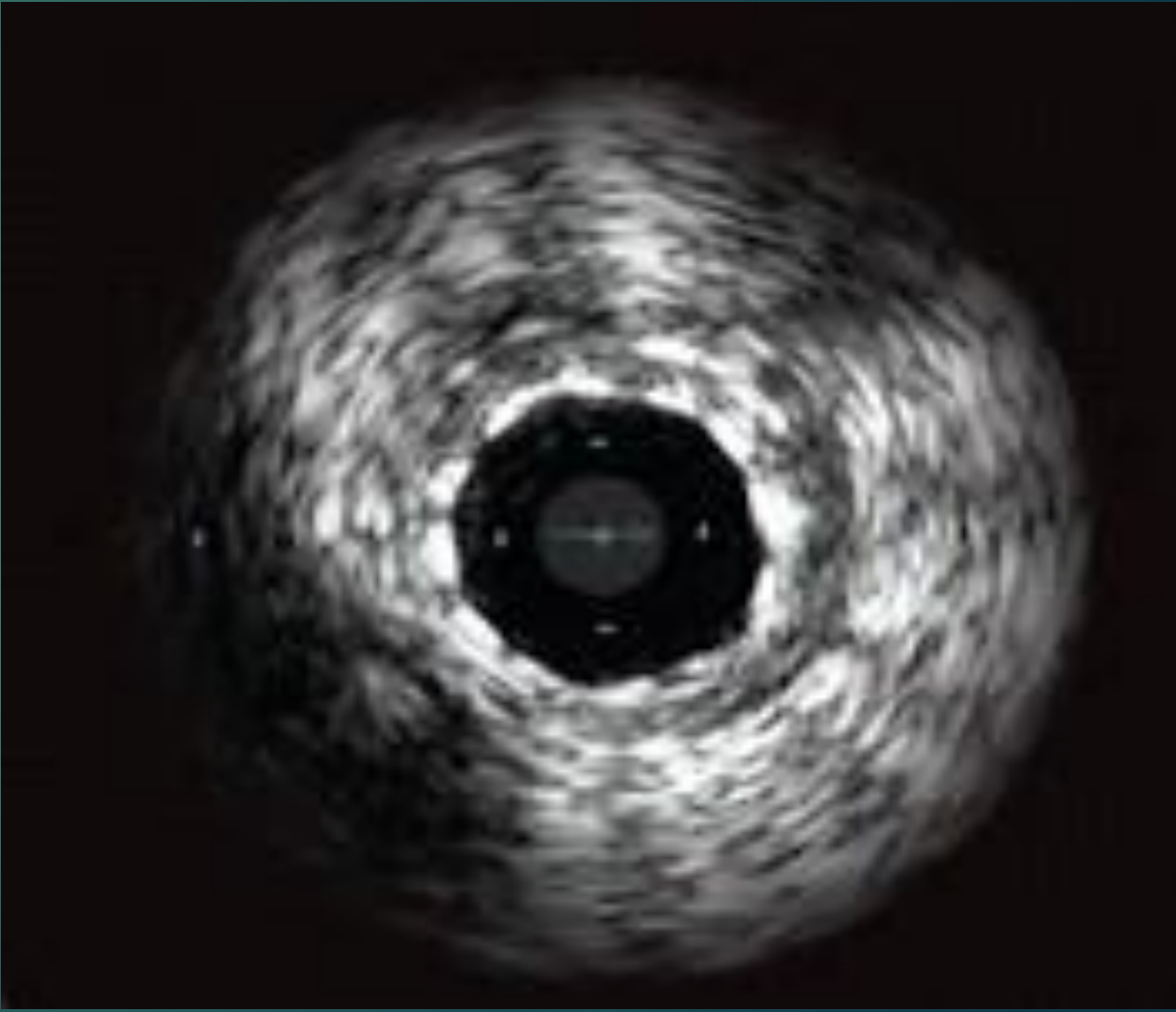
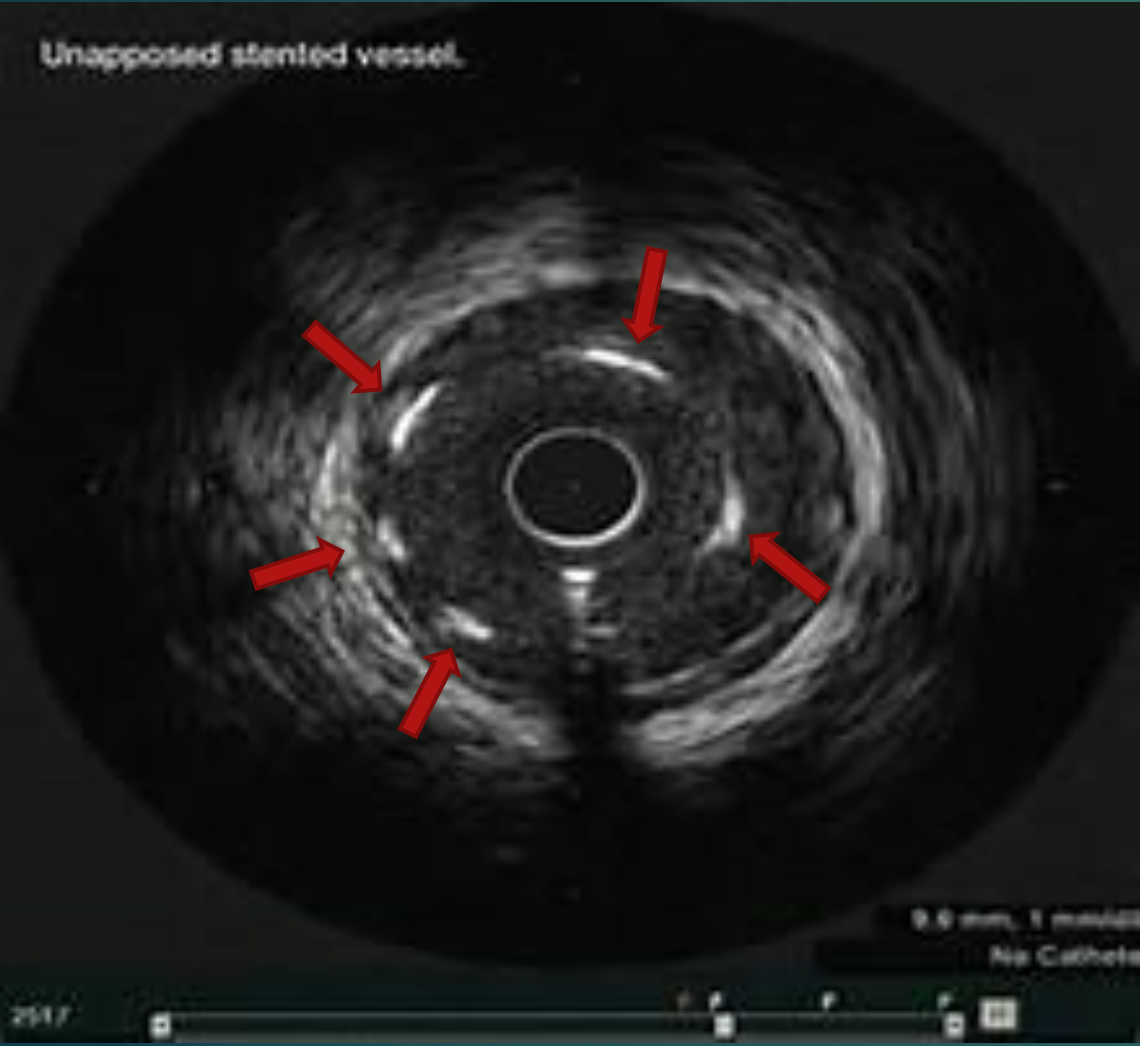


Example Images

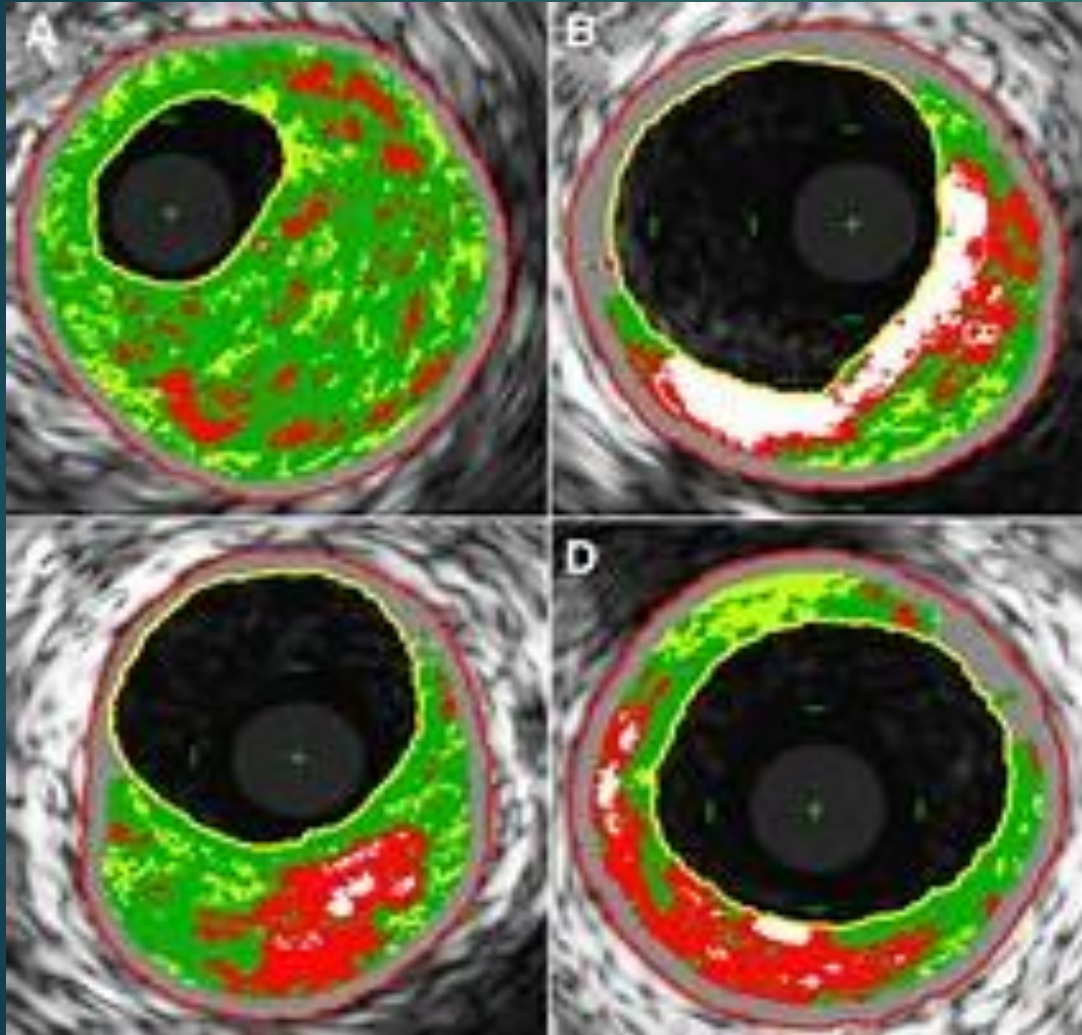
IVUS IMAGING



Example Images

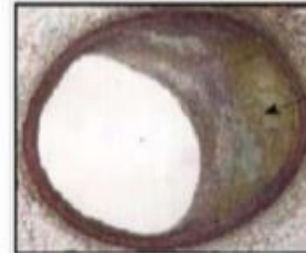


Example Images



Fibrous

Densely packed bundles of collagen fibers with no evidence of intra-fiber lipid accumulation. No evidence of macrophage infiltration. Appears dark yellow on Movat stained section.



Fibro-lipidic

Loosely packed bundles of collagen fibers with regions of lipid deposition present. These areas are cellular and no cholesterol clefts or necrosis are present. Some macrophage infiltration. Increase in extracellular matrix. Appears turquoise on Movat stained section.



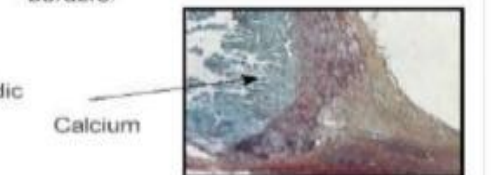
Lipid Core

Highly lipidic necrotic region with remnants of foam cells and dead lymphocytes present. No collagen fibers are visible and mechanical integrity is poor. Cholesterol clefts and micro calcifications are visible.



Calcium

Focal area of dense calcium. Appears purple on Movat. Usually falls out section, but calcium crystals are evident at borders.

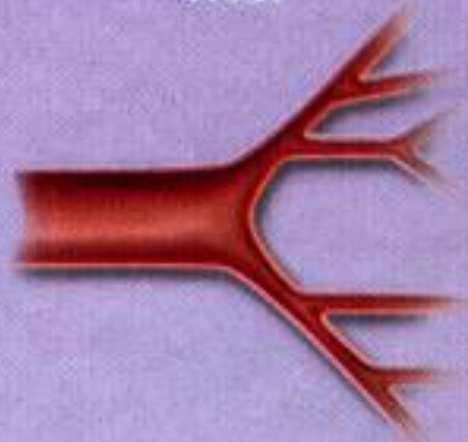




Fractional Flow Reserve (FFR)

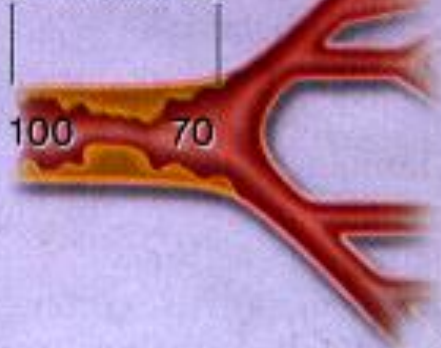
Normal Artery

Rest



Normal microvascular tone

$\Delta P = 30$ mm Hg



Partial microvascular dilatation

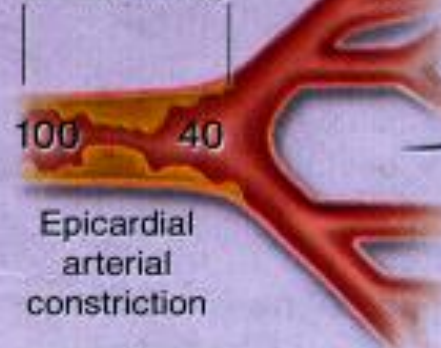
Exercise



Epicardial arterial dilatation

Complete microvascular dilatation

$\Delta P = 60$ mm Hg

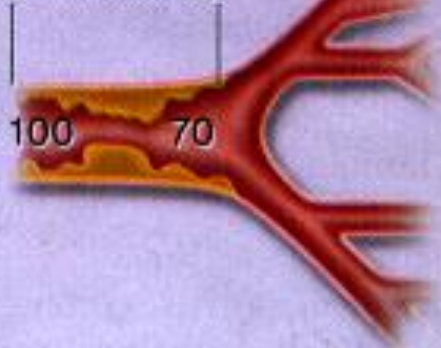


Epicardial arterial constriction

Complete microvascular dilatation

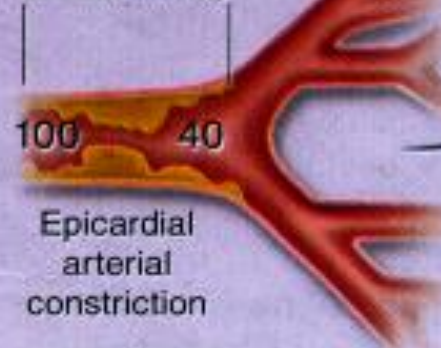
Atherosclerotic Artery

$\Delta P = 30$ mm Hg



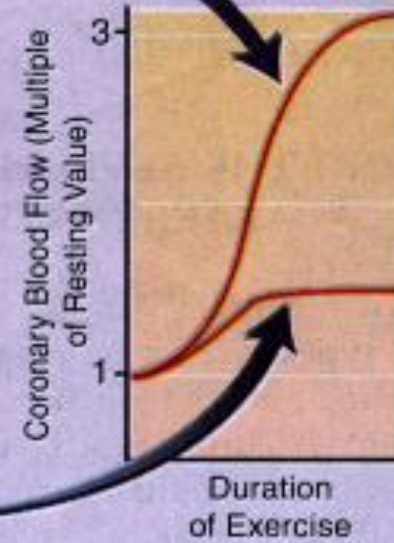
Partial microvascular dilatation

$\Delta P = 60$ mm Hg



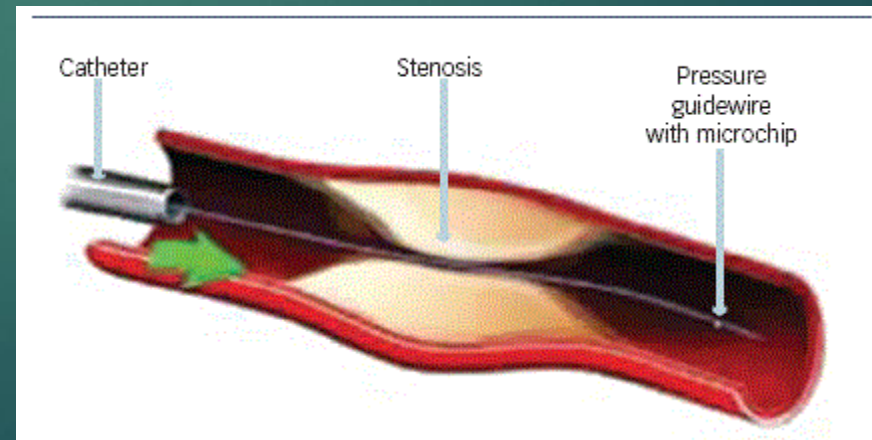
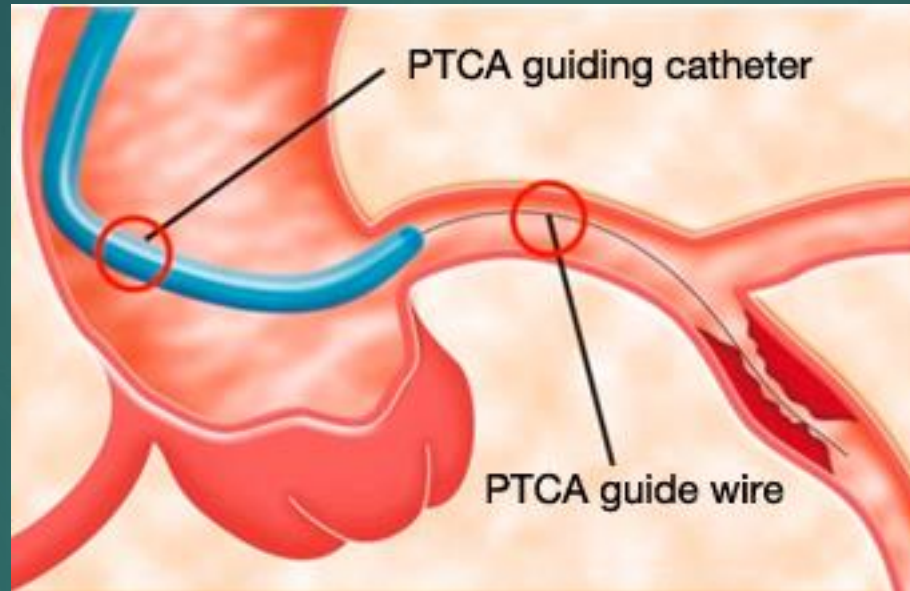
Epicardial arterial constriction

Complete microvascular dilatation



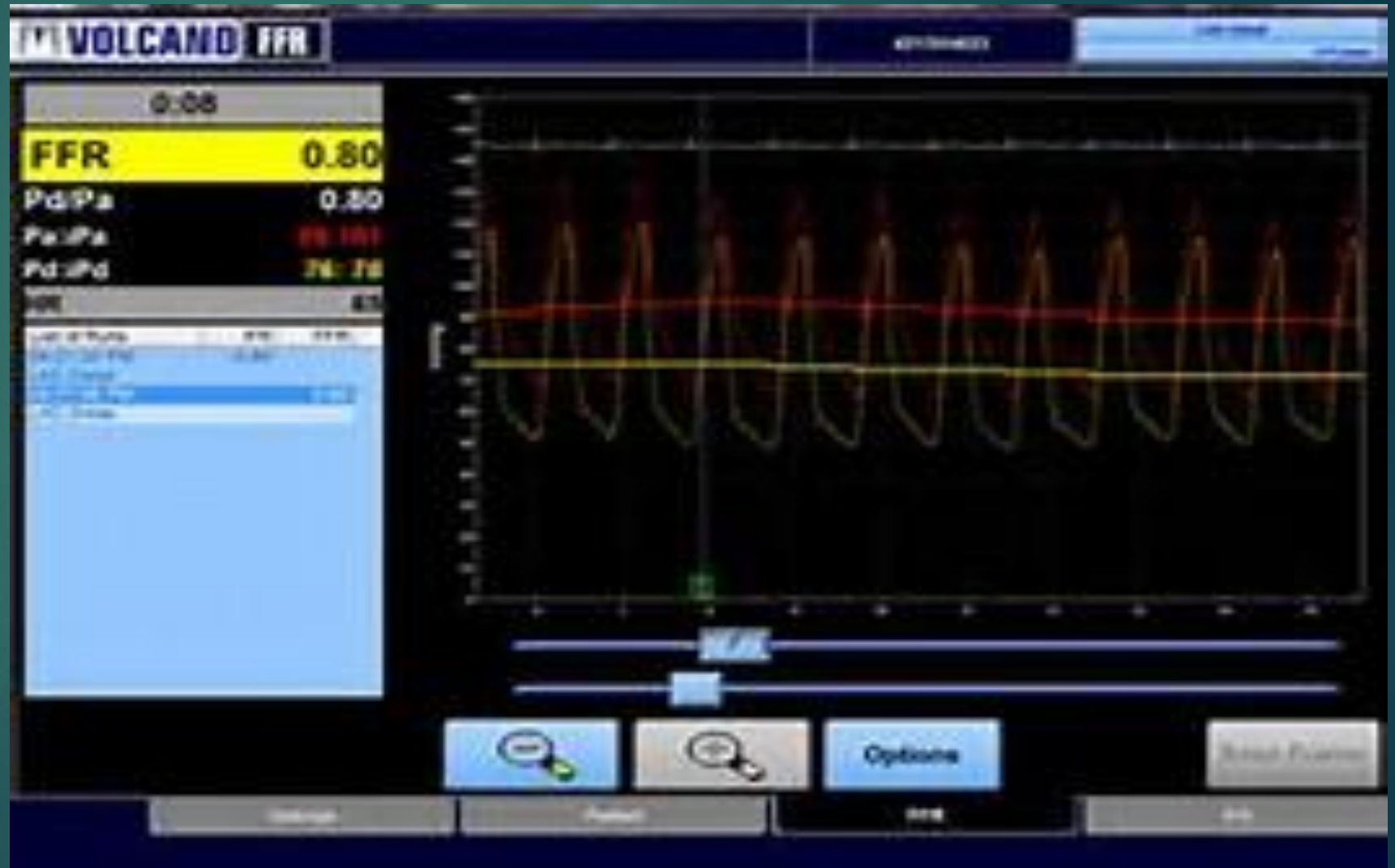
Fractional Flow Reserve

- How is FFR performed?



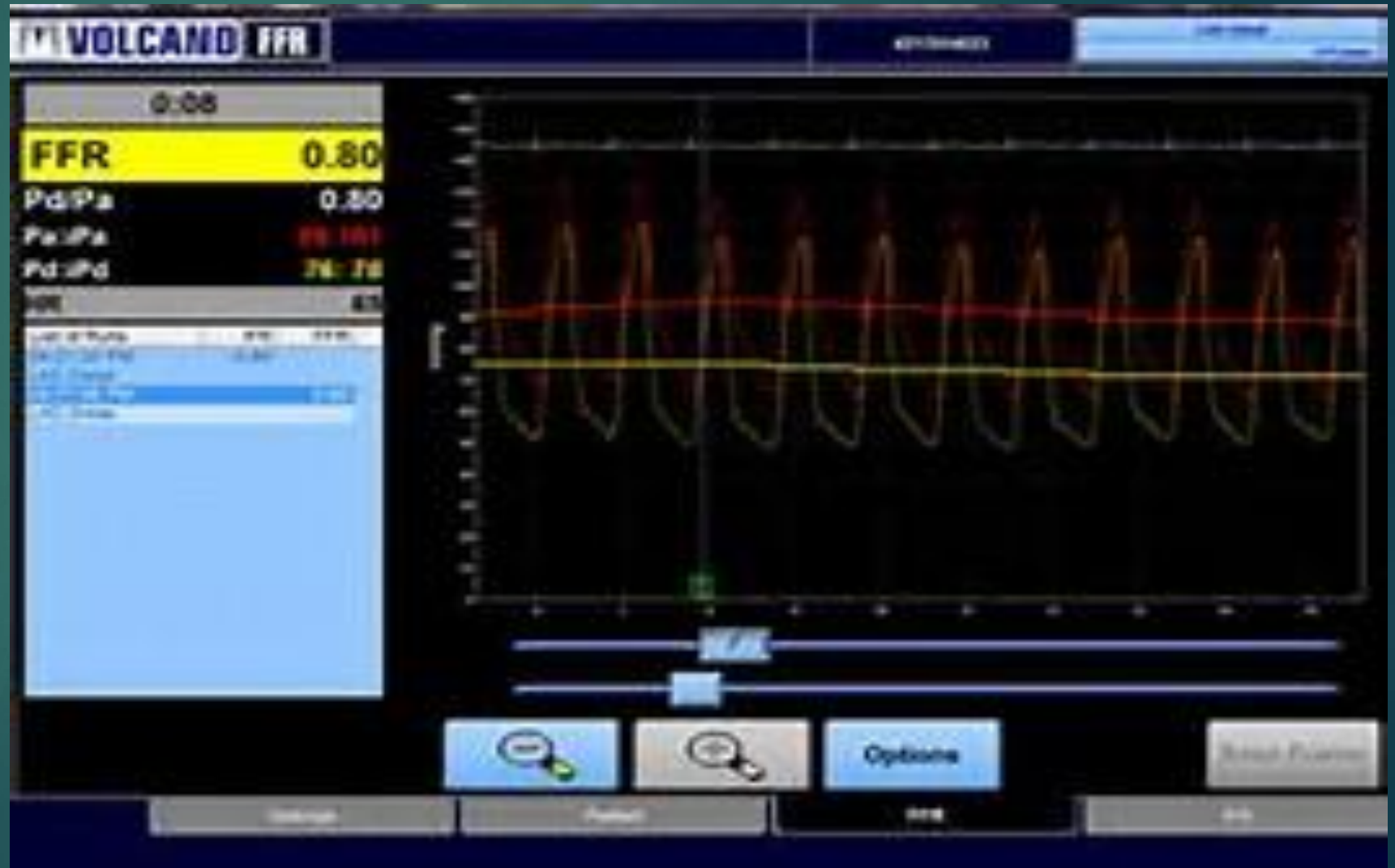
Fractional Flow Reserve

- Why do we use it?

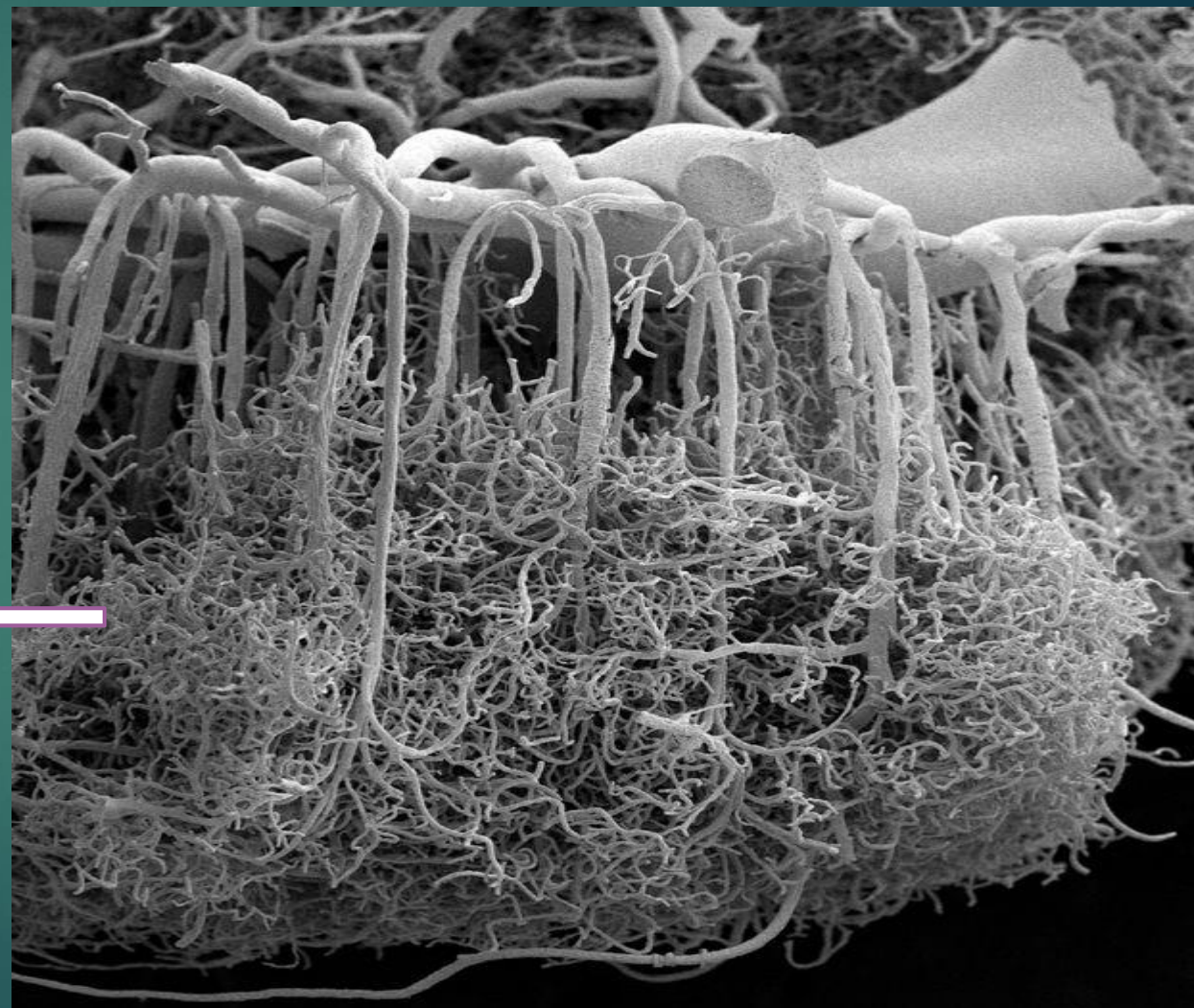
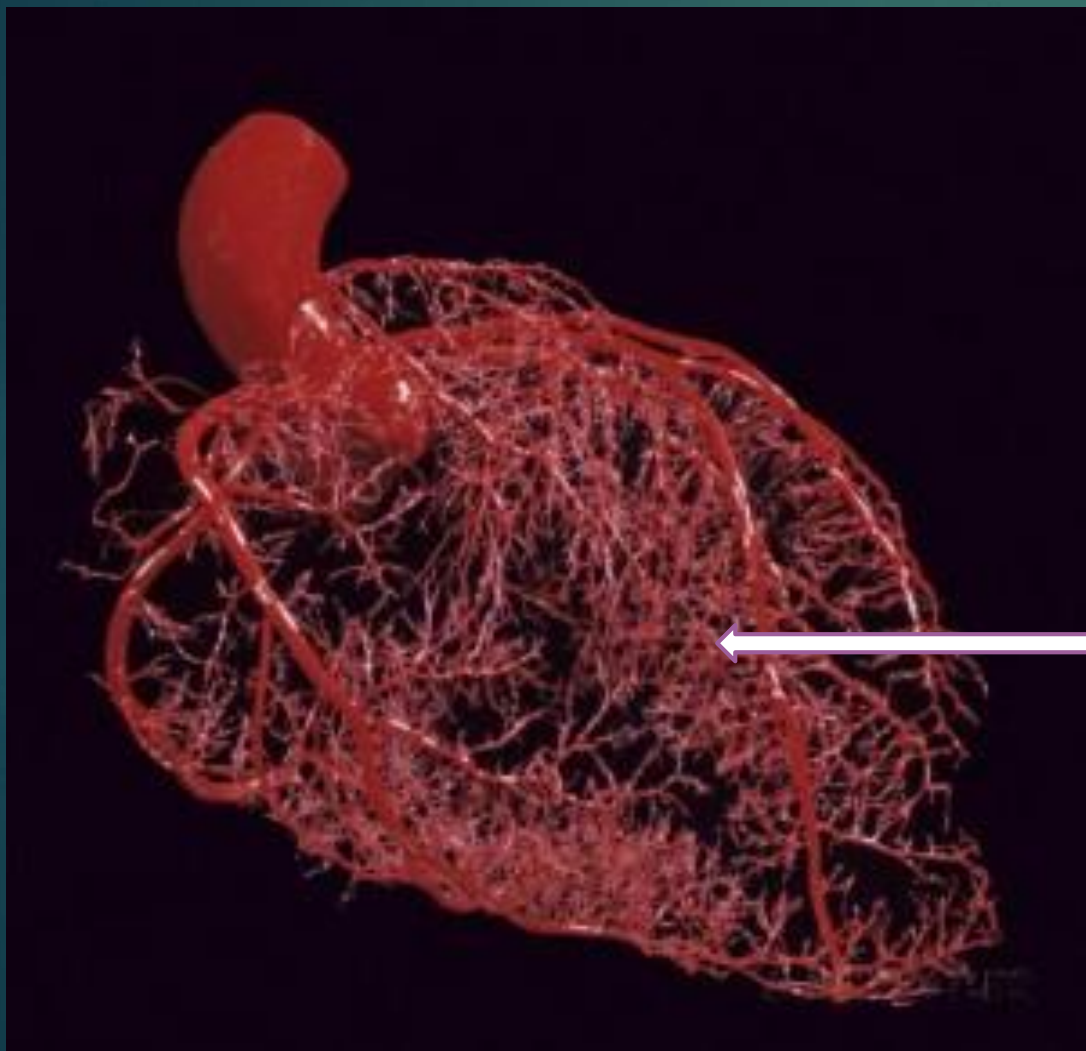


Fractional Flow Reserve

- What does that mean?

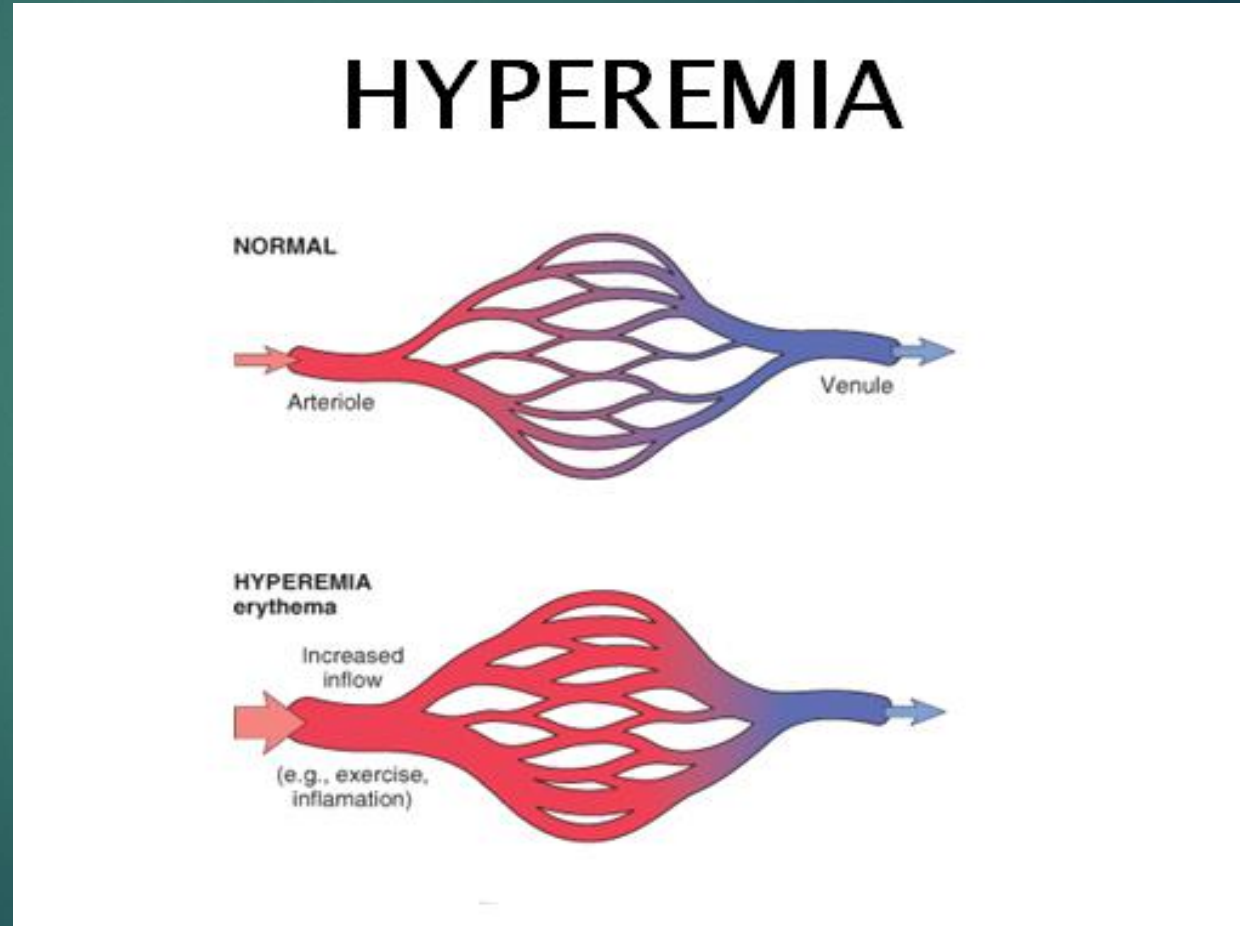


Fractional Flow Reserve

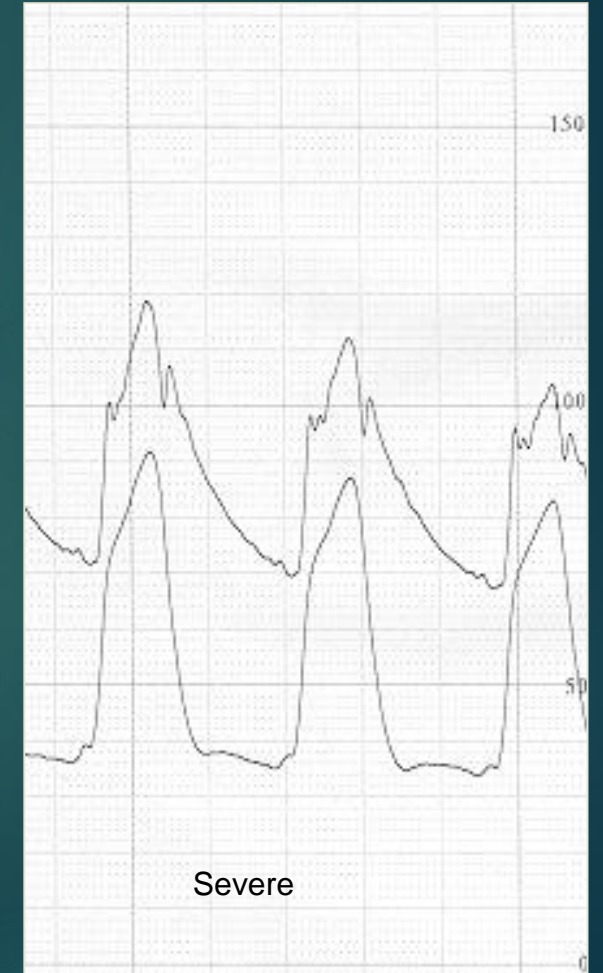
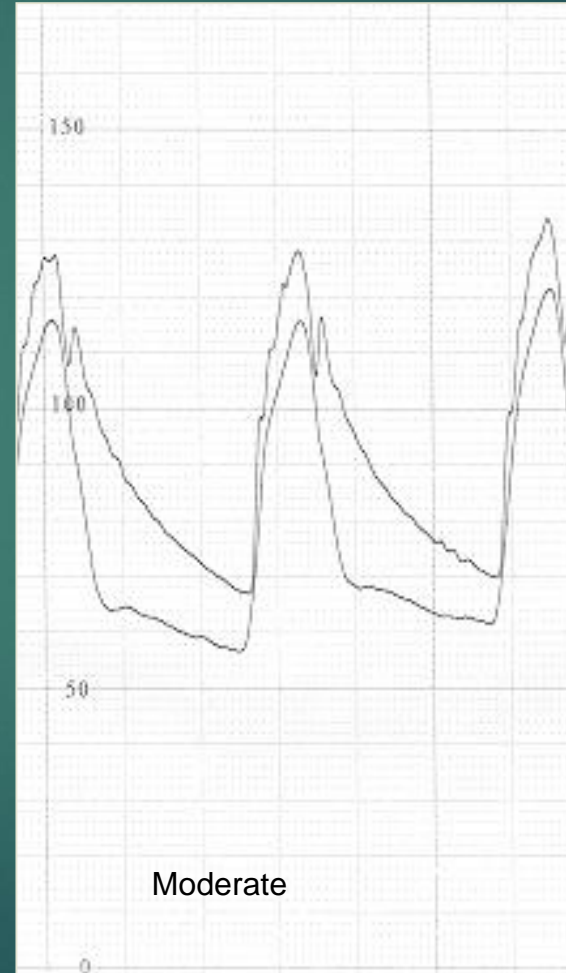
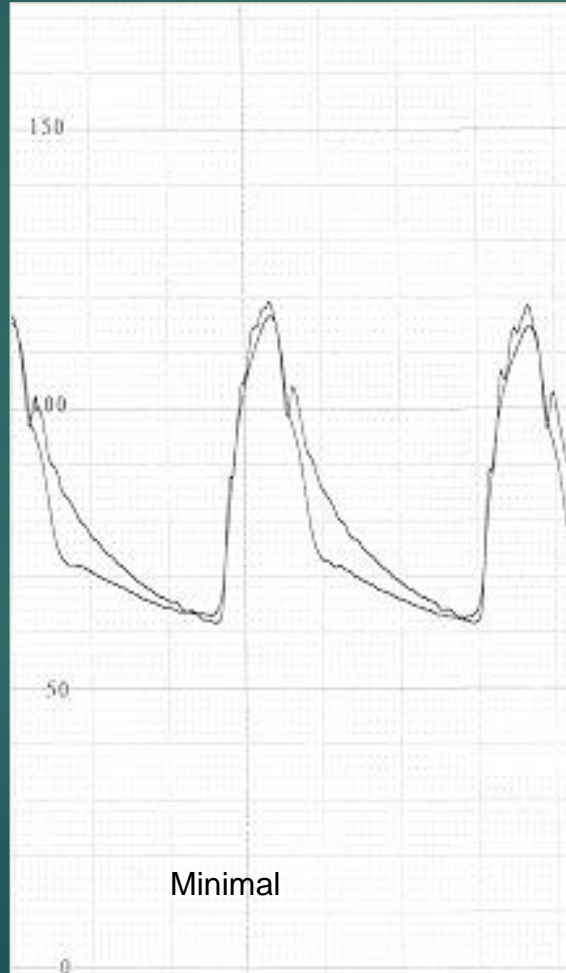
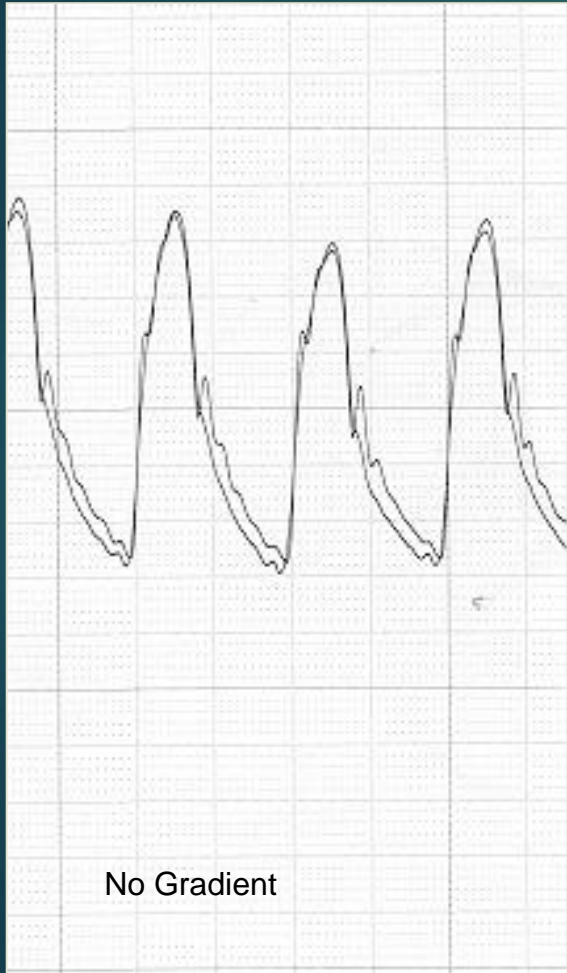


Fractional Flow Reserve

- Hyperemia = the increase in blood perfusion to different tissues in the body through dilation of the microvasculature.

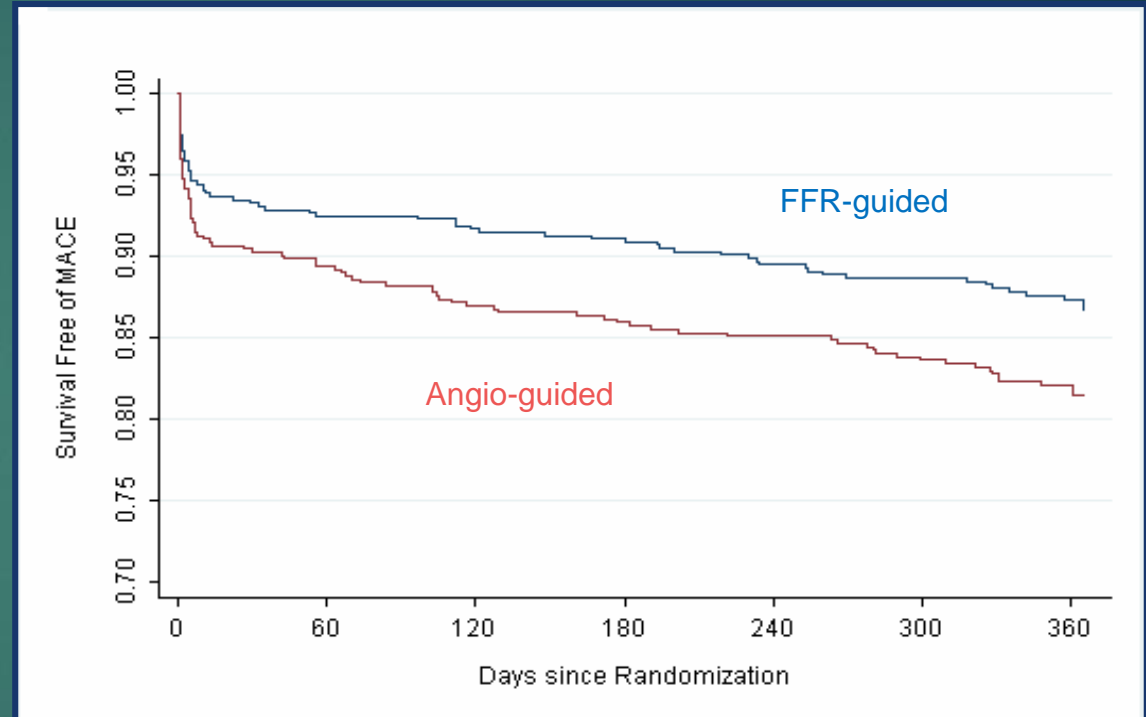


Fractional Flow Reserve



Fractional Flow Reserve

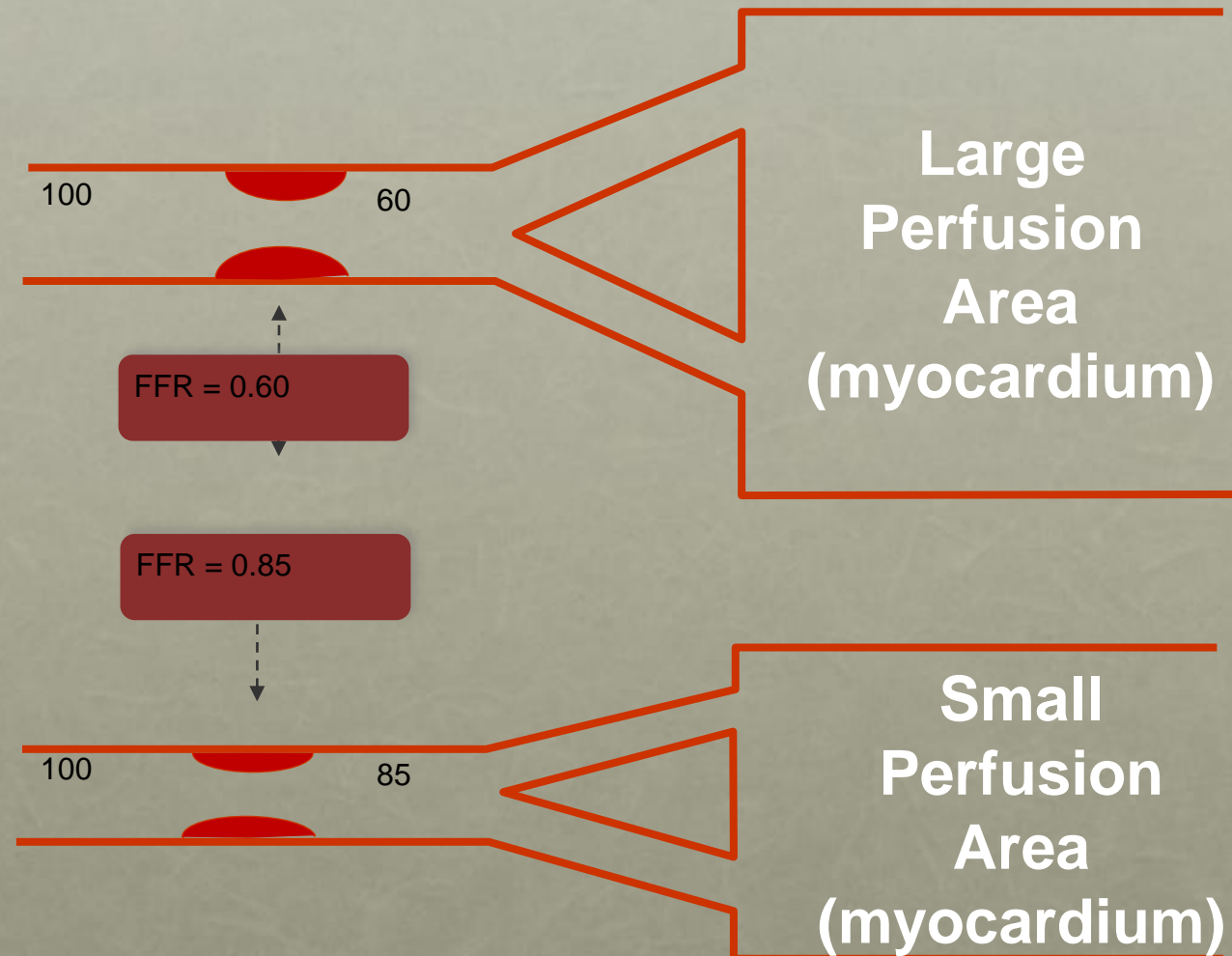
- FAME Study



Tonino, et al. New England Journal of Medicine 2009; 360:213-24.

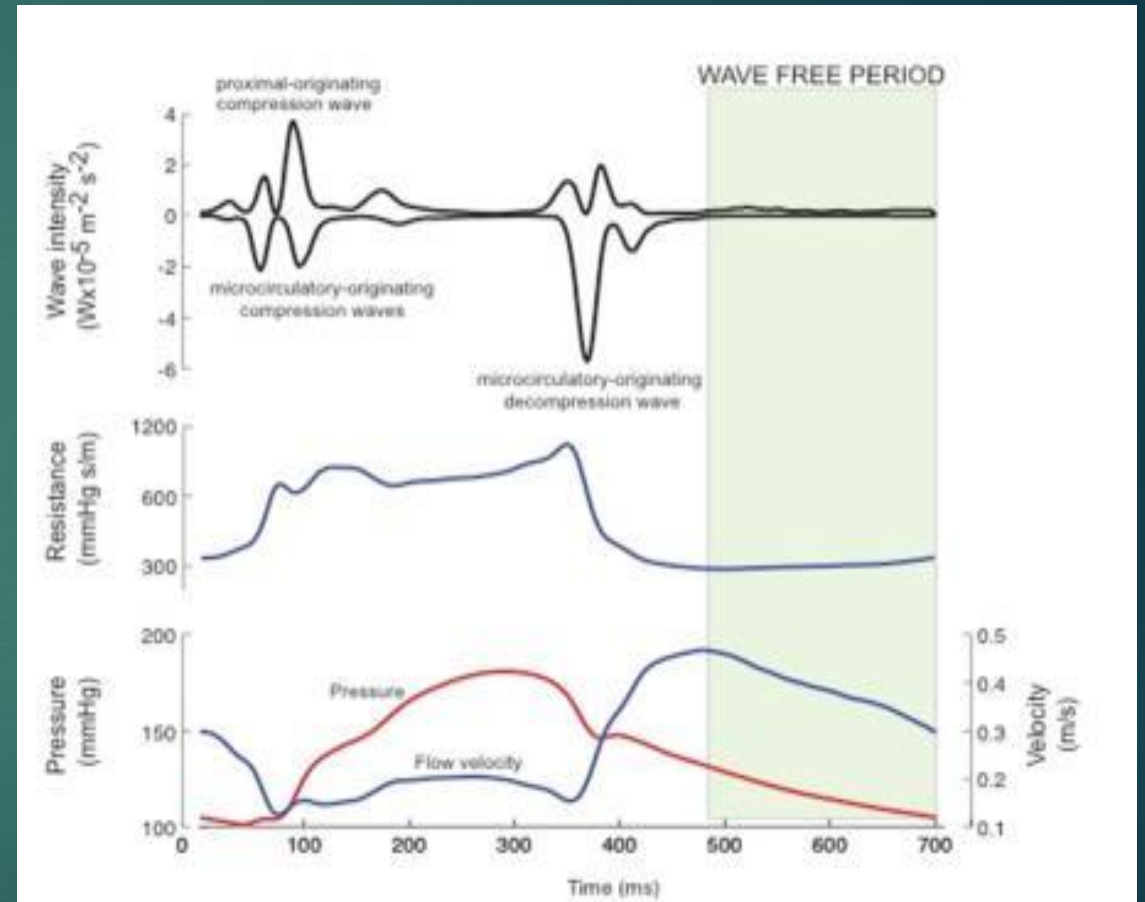
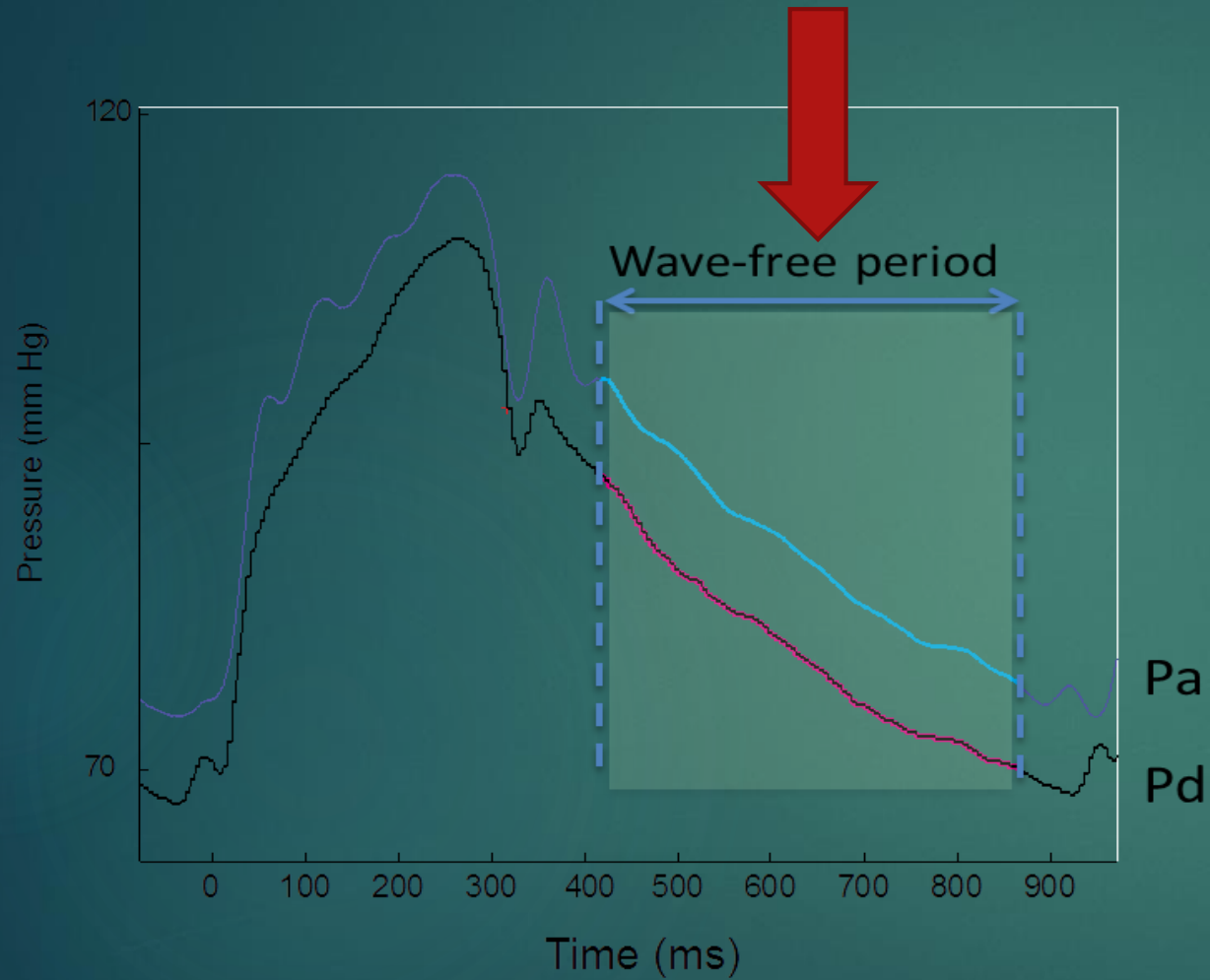
The Same, Yet Different...

Identical % Stenosis But Different Physiologic Significance



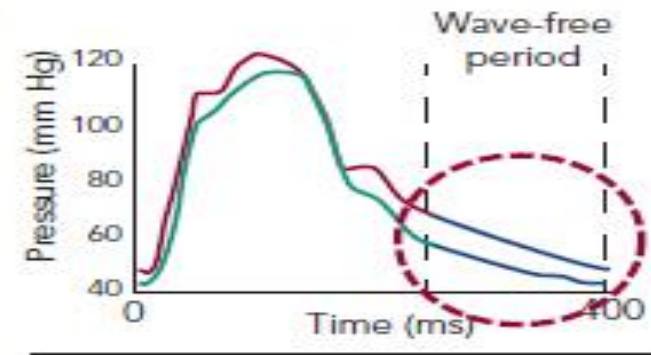
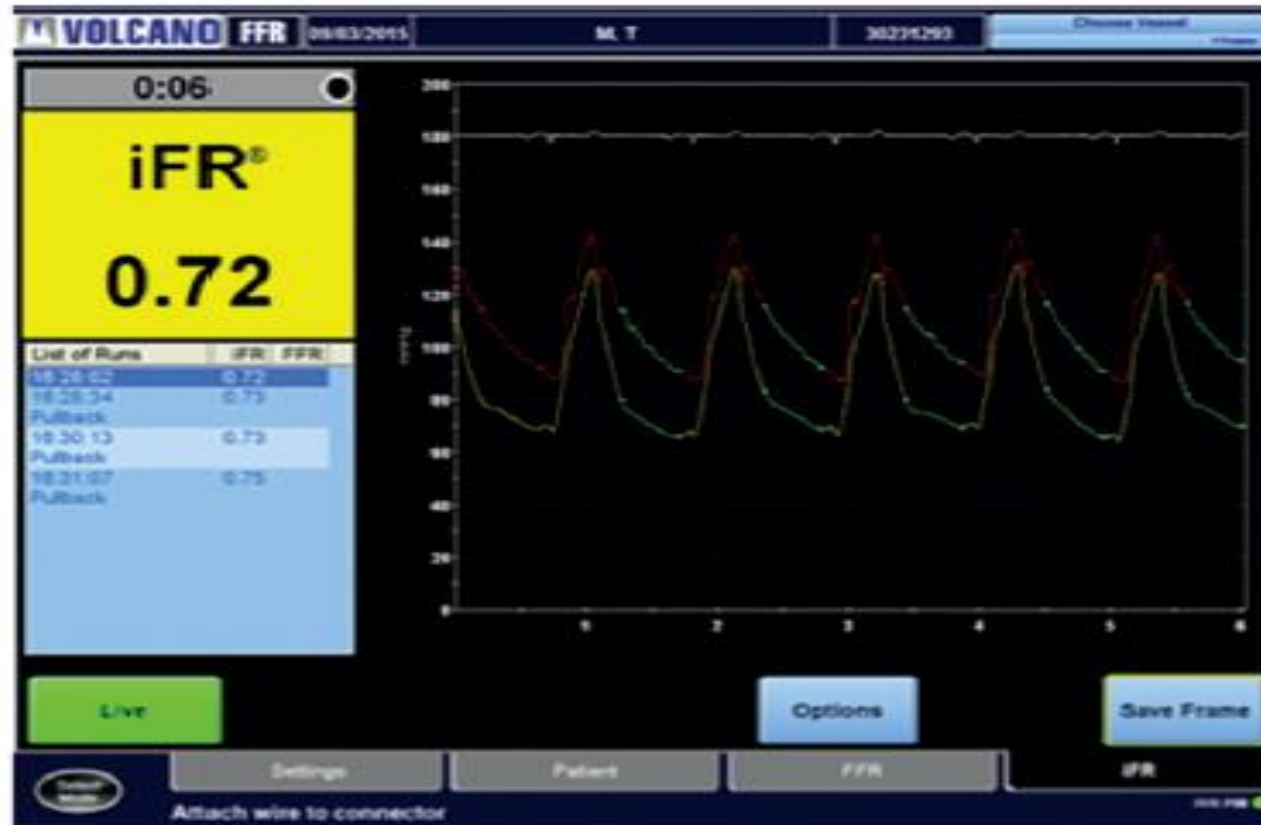
MLD, cross-sectional area, and stenosis resistance are identical, but due to the different sizes of the perfusion territory the physiologic severity is different!

iFR



iFR

Figure 1: The iFR is Identified in Real-time Permitting Beat-by-beat Calculation of iFR

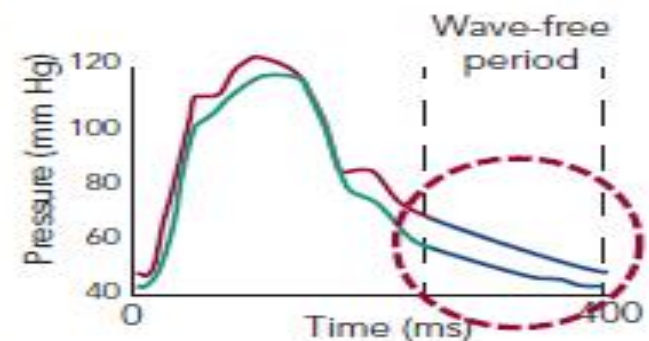
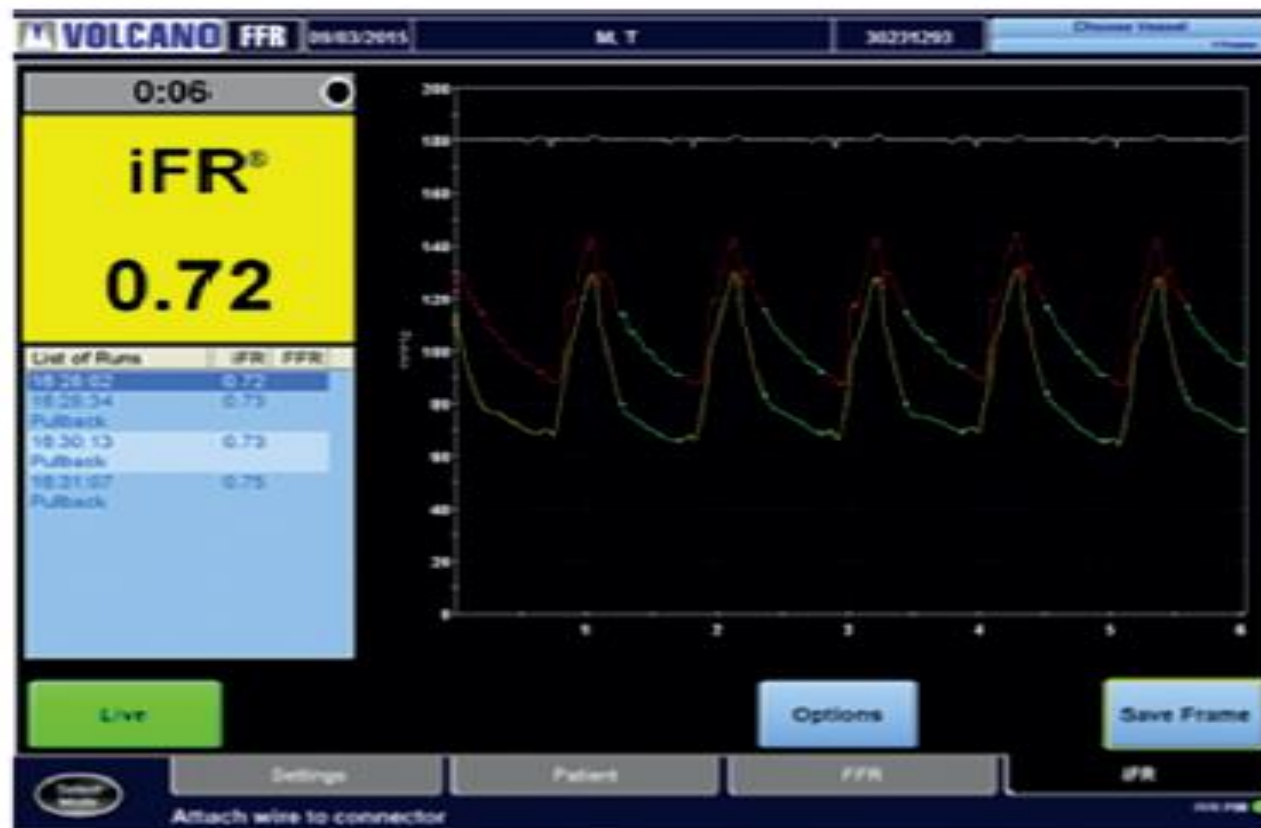


$$\frac{P_{d \text{ wave-free period}}}{P_{a \text{ wave-free period}}} = \text{iFR}$$

The wave-free period is automatically identified and marked with a green line. Instantaneous wave-free ratio (iFR) is the pressure ratio calculated during this phase of the cardiac cycle.

iFR

Figure 1: The iFR is Identified in Real-time Permitting Beat-by-beat Calculation of iFR

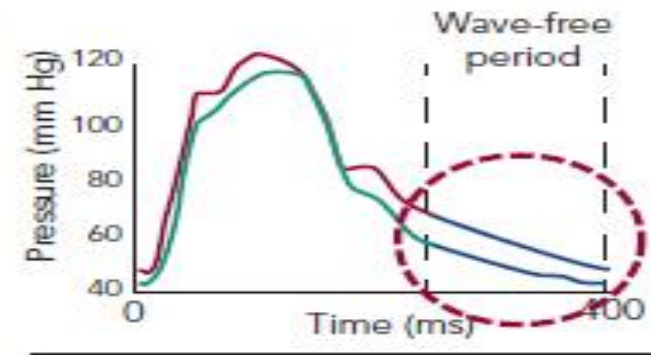


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iFR

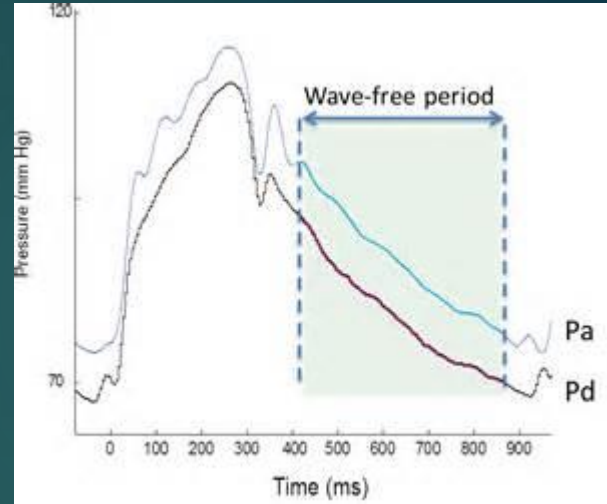
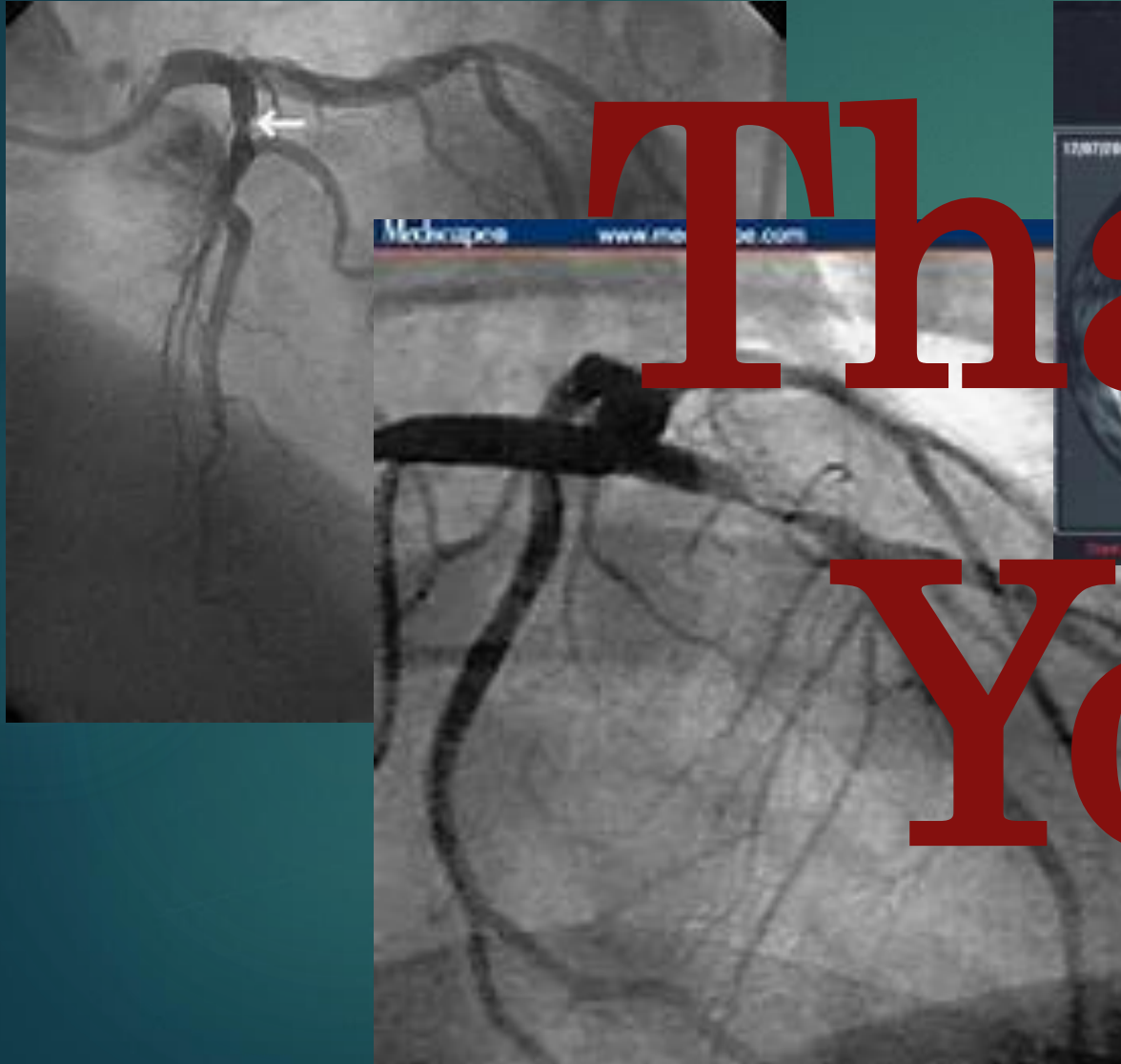
Figure 1: The iFR is Identified in Real-time Permitting Beat-by-beat Calculation of iFR



$$\frac{P_d \text{ wave-free period}}{P_a \text{ wave-free period}} = \text{iFR}$$

The wave-free period is automatically identified and marked with a green line. Instantaneous wave-free ratio (iFR) is the pressure ratio calculated during this phase of the cardiac cycle.

Closing



Thank
You

$$R = \frac{\text{Distal Coronary Pressure (Pd)}}{\text{Proximal Coronary Pressure (Pa)}} \quad (\text{During Maximum Hyperemia})$$

