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

- Normal
- Fatty Streak
- Fibrous Plaque
- Occlusive Atherosclerotic Plaque
- Plaque Rupture/ Fissure & Thrombosis

Disease progression:
- Unstable Angina
- MI
- Coronary Death
- Stroke
- Critical Leg Ischemia

Vascular Remodeling

ESS = Endothelial Shear Stress
Vascular remodeling

Natural Progression of Atherosclerosis

- Normal
- Mild Disease
- Moderate Disease
- Late Disease

Vessel expansion to Maintain lumen size

Expansion stops and lumen narrows

“shoulder”

Lumen

Lipid core
Concentric vs Eccentric Plaques

Concentric stenosis

Eccentric stenosis (Type I)

Eccentric stenosis (Type II)

Multiple irregularities

Cross-sectional view

Longitudinal or Angiographic view
Concentric vs Eccentric Plaques
Difficulties in assessing lesion severity by angiography alone.
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Vessel Wall Remodeling & Plaque Disruption

Normal vessel → Minimal CAD → Mild to Moderate Asymptomatic CAD → Acute CAD

Early Plaque
IEL - EEL expansion
Plaque Disruption

Pitfalls of Coronary Angiography
Lumen-o-gram

Difficulties in assessing lesion severity by angiography alone.
IVUS Basics
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IVUS stands for Intra Vascular Ultra Sound.
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
Example Images
Example Images
Example Images

Legend:

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.

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 microcalcifications are visible.

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.

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)
Fractional Flow Reserve

Rest
- Normal Artery
  - Normal microvascular tone
  - $\Delta P = 30 \text{ mm Hg}$
  - 100 70

Exercise
- Epicardial arterial dilatation
- Complete microvascular dilatation
- $\Delta P = 60 \text{ mm Hg}$
  - 100 40

Atherosclerotic Artery
- Partial microvascular dilatation
- Complete microvascular dilatation

Coronary Blood Flow (Multiple of Resting Value)

Duration of Exercise
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
Hyperemia = the increase in blood perfusion to different tissues in the body through dilation of the microvasculature.
Fractional Flow Reserve

- No Gradient
- Minimal
- Moderate
- Severe
Fractional Flow Reserve

• FAME Study

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

Instantaneous Free Wave Ratio
Figure 1: The iFR is Identified in Real-time Permitting Beat-by-beat Calculation of 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.
Figure 1: The iFR is Identified in Real-time Permitting Beat-by-beat Calculation of iFR

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