Fundamental and IVUS measurement

Myeong-Ki Hong, M.D., Ph.D

Professor of Medicine
Department of Medicine,
University of Ulsan College of Medicine
Asan Medical Center, Seoul, Korea
We needed another method

Index procedure 1-year follow-up
We needed another method

<table>
<thead>
<tr>
<th>Cross Section</th>
<th>RAO View</th>
<th>LAO View</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>B</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>C</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>
IVUS is a solution!
Contents

- Basic Physics and Equipment
- Image Acquisition and IVUS Artifacts
- Histology
- Quantitative and Qualitative Assessment
- Reporting
Contents

- Basic Physics and Equipment
- Image Acquisition and IVUS Artifacts
- Histology
- Quantitative and Qualitative Assessment
- Reporting
Basic Physics of Sound

- Sound is a physical phenomenon that transfers energy from one point to another.

- Sound can pass only through matter.

- Ultrasound can be focused into small, well-defined beams that can probe the human body and interact with the tissue structures to form images.
Piezoelectricity

- Piezo- : from piezein (Greek), squeeze or press
- Conversion electricity to sound and vice versa

When a piezoelectric crystal is placed in an electric field, or when charges are applied by external means to its faces, the crystal exhibits strain, i.e. the dimensions of the crystal change.
Ultrasound imaging process

- Electric impulse
- Crystal
- Sound beam
- Returning beam
## Comparison of IVUS with other ultrasound

<table>
<thead>
<tr>
<th>Technique</th>
<th>Transducer size (cm)</th>
<th>Depth (cm)</th>
<th>Intervening tissues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans-thoracic</td>
<td>&gt; 2</td>
<td>~3 – 20</td>
<td>Skin, fat, muscle</td>
</tr>
<tr>
<td>Trans-esophageal</td>
<td>&lt; 1.2</td>
<td>~2 – 20</td>
<td>Esophagus, atrium</td>
</tr>
<tr>
<td>Intravascular</td>
<td>&lt; 0.26</td>
<td>~0.05 – 4</td>
<td>blood</td>
</tr>
</tbody>
</table>
In early period
Equipment

Mechanical systems

Electronic systems
Image quality

- Spatial resolution
  - The ability to discriminate small objects within the ultrasound image
  - Axial: parallel to the beam
  - Lateral: perpendicular to both the beam and the catheter
Image Acquisition
pullback method

• Manual pullback
  - to concentrate on specific regions of interest
  - But, possible to skipping over and not to perform precise measurement
  - not reproducible

• Motorized pullback
  - precise, reproducible
  - to reconstruct image (L-mode, 3D)
Image Acquisition
Longitudinal display (L-mode)

• For spatial orientation, assessment of length, and distribution of plaque
IVUS artifacts
non-uniform rotational distortion (NURD)

Full sector NURD
Isolated sector NURD
IVUS artifacts
air bubble
Contents

- Basic Physics and Equipment
- Image Acquisition and IVUS Artifacts
- Histology
- Quantitative and Qualitative Assessment
- Reporting
Histology and IVUS

Adventitia

Ring-down artifact

Normal intima

IVUS catheter
Histology and IVUS

- Intimal thickening
- Fibrous cap
- Lipid pool
- Echolucent intimal area
The Three-Layered Appearance

border identification

Adventitia  Media  Intima
The Three-Layered Appearance

border identification

1. **Adventitia**: the outer covering of the artery

2. **Media**: the actual wall of the artery

3. **Intima**: a layer of endothelial and other cells that make direct contact with the blood inside the artery

4. **Lumen**: the actual open channel of the artery through which the blood flows.
Quantitative measurement
lumen measurements
Quantitative measurement
lumen measurements

Measurements On Current Frame

<table>
<thead>
<tr>
<th>Area (mm^2)</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lumen</strong></td>
<td>Mean 2.03 Min 1.81 Max 2.38 Min/Max 0.76</td>
</tr>
<tr>
<td><strong>Vessel</strong></td>
<td>Mean 4.47 Min 4.27 Max 4.74 Min/Max 0.90</td>
</tr>
<tr>
<td><strong>Stent</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Plaque</strong></td>
<td>12.36 (79.6% of Vessel) Comparative Lumen Area</td>
</tr>
<tr>
<td><strong>NIH</strong></td>
<td></td>
</tr>
</tbody>
</table>
Quantitative measurement
atheroma measurements
Quantitative measurement

atheroma measurements

Atheroma

= EEM
Quantitative measurement
atheroma measurements

Atheroma = EEM - Lumen
Quantitative measurement
atheroma measurements

Atheroma eccentricity

= $\frac{A - B}{A}$
Quantitative measurement
atheroma measurements

Atheroma burden

$= \frac{C - D}{C}$
Quantitative measurement
stent measurements
Quantitative measurement
stent measurements

<table>
<thead>
<tr>
<th></th>
<th>Area (mm^2)</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel</td>
<td>20.99</td>
<td>5.19</td>
</tr>
<tr>
<td>Stent</td>
<td>10.55</td>
<td>3.69</td>
</tr>
<tr>
<td>Plaque</td>
<td></td>
<td>3.49</td>
</tr>
<tr>
<td>NIH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparative Lumen Area
Dicotomous Classification of Remodeling

Positive remodeling

Intermediate remodeling

Negative remodeling

Proximal reference  Lesion  Distal reference
Contribution of inadequate arterial remodeling to the development of focal coronary artery stenoses: an IVUS study

ASAN MEDICAL CENTER

EEM CSA: 9.0 mm²
Lumen CSA: 2.6 mm²

EEM CSA: 21.2 mm²
Lumen CSA: 14.2 mm²

STENT CSA: 10.9 mm²

Stenting alone

Negative remodeling

Negative remodeling

Stenting alone
ASAN MEDICAL CENTER

EEM CSA: 23.9 mm²
Lumen CSA: 2.3 mm²

EEM CSA: 18.6 mm²
Lumen CSA: 10.3 mm²

STENT CSA 15.4 mm²

Positive remodeling

Stenting After DCA
Quantitative measurement
negative remodeling
Atheroma Morphology

Normal
Atheroma Morphology

Soft plaque
Atheroma Morphology
fibrotic plaque
Atheroma Morphology
Calcium
Atheroma Morphology
rupture
Atheroma Morphology

lipid core
Atheroma Morphology

thrombus
Contents

- Basic Physics and Equipment
- Image Acquisition and IVUS Artifacts
- Histology
- Quantitative and Qualitative Assessment
- Reporting
Reporting of IVUS results

✓ Appropriate patient demographic information and date
✓ Indication and brief description of procedure
✓ Basic findings: MLD, minimum stent area, or plaque burden…
✓ Plaque features: dissection, calcium, or thrombus…
✓ Changes of therapy by IVUS
✓ IVUS-related complications and any consequent therapy.

In my opinion ....

When you meet the complex cases, IVUS will help you at any time and answer you clearly about difficult questions.
Image quality

- Contrast resolution
  - the distribution of the gray scale of the reflected signal and is often referred to as dynamic range