Virtual Histology
Arterial Reconstruction
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Virtual Histology™ IVUS

Only the envelope amplitude (echo intensity) is used in formation of the gray-scale IVUS image.

Amplitude AND Frequency of Echoes used in Virtual Histology

Frequency of echo signal can also vary, depending on the tissue.
Teaching the Computer
Do the different frequencies correspond to different types of tissue?

- Calcium
- Fibrous
- Fibro-lipidic
- Lipid core
VH: Current Development

- *Eagle Eye* Analysis Tree
- Automatic Border Detection
- Validation!
VH Current Development

- Licensed to Volcano Therapeutics, 2002
- Available on *Invision* system, July 2004
  - *EagleEye* catheter
Virtual Histology

- *Eagle Eye Analysis Tree*
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- Validation!
What’s the Problem?
Border Detection

\[ E_{\text{contours}} = \int_0^1 \left( \alpha(s) E_L(s) + \beta(s) E_M(s) + \gamma(s) E_P(s) \right) ds \]

Each term in the 3 energy calculations has a separate weight and each of \( E_L \), \( E_M \), and \( E_P \) have weights.

\[ \left| V_{(n-1) \text{mod} N} - 2V_{n \text{mod} N} + V_{(n+1) \text{mod} N} \right|^2 \]

1) Transverse curvature

2) Transverse rigidity (keeps line straight)

3) Radial RF Gradient

4) Radial pre-process VH Gradient

\[ \frac{\min_{RF} - G_{RF}}{\max_{RF} - \min_{RF}} \]

\[ \frac{\min_{VH} - G_{VH}}{\max_{VH} - \min_{VH}} \]
Automatic Border detection
Virtual Histology

- *Eagle Eye Analysis Tree*
- *Automatic Border Detection*
- Validation!
How reproducible is VH?

- Three patients
  - 30MHz Ultracross
  - Two pullbacks with same catheter
  - Jim Margolis, MD

- Calculate geometry and composition
  - Borders traced on separate days
# Volume Data

<table>
<thead>
<tr>
<th>Composition</th>
<th>Pullback 1</th>
<th></th>
<th>Pullback 2</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>mm³</td>
<td>%</td>
<td>mm³</td>
<td>%</td>
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<tr>
<td>Fibrous Volume:</td>
<td>29.57</td>
<td>53.07</td>
<td>30.85</td>
<td>53.05</td>
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<tr>
<td>Fibro-Lipidic Volume:</td>
<td>1.50</td>
<td>2.68</td>
<td>1.44</td>
<td>2.47</td>
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<tr>
<td>Calcified Volume:</td>
<td>0.75</td>
<td>1.34</td>
<td>0.90</td>
<td>1.54</td>
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<tr>
<td>Lipid Core Volume:</td>
<td>23.91</td>
<td>42.90</td>
<td>24.98</td>
<td>42.94</td>
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</table>

<table>
<thead>
<tr>
<th>Geometry</th>
<th>mm³</th>
<th>mm³</th>
<th>Diff</th>
<th>%</th>
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<tbody>
<tr>
<td>Lumen Volume:</td>
<td>83.45</td>
<td>82.50</td>
<td>0.95</td>
<td>1.14%</td>
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<tr>
<td>Vessel Volume:</td>
<td>190.59</td>
<td>191.13</td>
<td>-0.54</td>
<td>-0.28%</td>
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<tr>
<td>Plaque Volume:</td>
<td>107.14</td>
<td>108.63</td>
<td>-1.48</td>
<td>-1.38%</td>
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</tbody>
</table>
Two pullbacks

Miami_AA_ROI1_RCA1

Frame Number

CSA (mm²)

Lipid Core Cross-Sectional Area
Fibro-Lipidic Cross-Sectional Area
Fibrous Cross-Sectional Area
Calcified Cross-Sectional Area

Distal

Proximal
Two pullbacks

Lipid Core Cross-Sectional Area
Fibro-Lipidic Cross-Sectional Area
Fibrous Cross-Sectional Area
Calcified Cross-Sectional Area

Frame Number
CSA (mm^2)

Distal  Frame Number  Proximal
Grey scale vs VH vs histopathology
Causes of Calcium?

- Inflammation
  - inflamed cells die and dump their Ca in the extracellular space leading to microcalcification (red)
  - LN with Scattered calcium (red with some Ca, shadow)
  - Larger, focal sites of calcium (red with Ca, +/-reverberations)

- intramural hemorrhage
Ability of Gray Scale ??
Summary

- Tissue interpretation with grey scale IVUS should be done with caution
- The initial data on the reproducibility of VH in clinical practice looks very promising
- Studies underway to determine clinical utility of VH
  - Systemic therapy
  - Device based therapy
Future studies

- VH built into IVUS system
  - EagleEye tree in Q2, 2004
  - “Real-time” capabilities
  - Automatic border detection
- Interface & Display
3D Plaque Composition

Fibrous; Fibro-lipidic; Lipidic-necrotic; Calcium