Topics to Discuss

- Grayscale echogenicity measures and features associated with unstable plaques
- Grayscale echogenicity measures and features used in research to assess risk for CV events
• Low grayscale median value (GSM)
  • Low GSM values near lumen surface
  • Juxtaluminal black area (JBA)
  • Black area with border (BAB)
• Discrete white areas (DWA)

Images: Dempsey PI “Structural Stability of Carotid Plaque and Symptomatology” (NIH funded study: R01 NS064034)
### Carotid Plaque Grayscale Ultrasound Features – Relationship to Plaque Tissue Composition

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>Grayscale Feature(s)</th>
<th>REF.</th>
</tr>
</thead>
<tbody>
<tr>
<td>El-Barghouty, et. al.</td>
<td>1996</td>
<td>52</td>
<td>GSM</td>
<td>2</td>
</tr>
<tr>
<td>Lal, et. al.</td>
<td>2002</td>
<td>10; 20</td>
<td>GSM</td>
<td>3</td>
</tr>
<tr>
<td>Sztajzel, et. al.</td>
<td>2005</td>
<td>28</td>
<td>GSM</td>
<td>4</td>
</tr>
<tr>
<td>Salem, et. al.</td>
<td>2014</td>
<td>126</td>
<td>GSM, JBA size, plaque area, plaque type, DWA</td>
<td>5</td>
</tr>
<tr>
<td>Doonan, et. al.</td>
<td>2016</td>
<td>160</td>
<td>PCA selected 39 plaque features</td>
<td>6</td>
</tr>
<tr>
<td>Mitchell et. al.</td>
<td>2017</td>
<td>38</td>
<td>GSM, DWA, JBA, BAB, Black area in one component, plaque type, plaque area</td>
<td>7</td>
</tr>
</tbody>
</table>
### Carotid Plaque Grayscale Ultrasound Features and Associations with Risk for Cerebrovascular Event

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
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<td>El-Barghouty, et. al.</td>
<td>1995</td>
<td>87</td>
<td>GSM</td>
<td>7</td>
</tr>
<tr>
<td>Elatrozy, et. al.</td>
<td>1998</td>
<td>80</td>
<td>GSM, percentage of echolucent pixels (PEP), homogeneity, entropy and contrast.</td>
<td>8</td>
</tr>
<tr>
<td>Johnsen, et. al.</td>
<td>2007</td>
<td>6226</td>
<td>GSM, plaque area, CIMT, Incident MI</td>
<td>9</td>
</tr>
</tbody>
</table>

### Histological Verification of Computerised Carotid Plaque Characterisation

- **N=52 patients**
- All patients had carotid endarterectomy
- Plaques with high GSM were associated with more fibrous content ($r=0.411$, $p<0.001$)
- Plaques with low GSM were associated with more hemorrhage and lipid content ($r=-0.351$, $p<0.05$)


### Pixel distribution analysis of B-mode ultrasound scan images predicts histologic features of atherosclerotic carotid plaques

- **N=10 volunteers**
- **N=19 patients (20 carotid plaques)**
- Range of median grayscale values for different tissue types
  - Blood 2 (0-4)
  - Lipid 12 (8-26)
  - Muscle 53 (41-76)
  - Fibrous Tissue 172 (112-196)
  - Calcium 221 (211-255)
- Pixel distribution analysis correlated significantly with plaque tissue types at histopathology examination (p all < 0.05)
- Symptomatic plaques were associated with more blood and lipid
- Asymptomatic plaques were associated with more calcium

## Carotid Plaque Grayscale Ultrasound Features - Associations with Risk for Cerebrovascular Event

<table>
<thead>
<tr>
<th>Author et al.</th>
<th>Year</th>
<th>n</th>
<th>Grayscale Feature</th>
<th>REF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicolaides et al.</td>
<td>2010</td>
<td>1121</td>
<td>GSM, JBA, DWA, plaque type, plaque area (Participants from the Asymptomatic Carotid Stenosis and Risk of Stroke Study (ACSRS))</td>
<td>10</td>
</tr>
<tr>
<td>Griffin et al.</td>
<td>2011</td>
<td>324</td>
<td>GSM, JBA</td>
<td>11</td>
</tr>
<tr>
<td>Ruiz-Ares et al.</td>
<td>2011</td>
<td>66</td>
<td>GSM</td>
<td>12</td>
</tr>
<tr>
<td>Kakkos et al.</td>
<td>2013</td>
<td>1121</td>
<td>JBA, GSM, plaque area, DWA presence</td>
<td>13</td>
</tr>
</tbody>
</table>

### Asymptomatic internal carotid artery stenosis and cerebrovascular risk stratification

- **N=1121**
- Participants ACSRS study, medical intervention vascular disease
- 50-99% carotid stenosis; asymptomatic
- Mean follow-up 48 months (6-96 months)
- Clinical features, plaque type 1,2,3, increased plaque area, DWA presence associated with increased risk for event
- ROC curves (predicted versus observed CV events)
  - AUC stenosis 0.59 (95% confidence interval [CI] 0.54-0.64)
  - AUC stenosis, clinical features 0.66 (0.62-0.72)
  - AUC stenosis, clinical features, plaque features 0.82 (0.78-0.86)

### Juxtaluminal hypoechoic area in ultrasonic images of carotid plaques and hemispheric symptoms

- **N=324**
- 50-99% stenosis; asymptomatic (n=139), symptomatic (185)
- JBA > 8mm² symptomatic plaques
- Multiple logistic regression model
  - Increasing stenosis (mild, moderate, severe)
  - GSM ≤ 15
  - JBA ≥ 8mm²
  - Identified high risk group of plaques
  - (OR, 6.7: 95% CI [408-10.91], p<0.001)

### Computer-Assisted Carotid Plaque Characterisation*

- **N=87 (148 plaques)**
- GSM < 32 55% incidence of cerebral infarction on brain CT
- GSM > 32 11% incidence of cerebral infarction on brain CT
- \(x^2 = 30.35, p<0.001, RR = 22, 95\% CI [4.7, 108])

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Carotid Plaque Grayscale Ultrasound Features and Associations with Cardiovascular Disease Risk Factors

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<td>2007</td>
<td>98</td>
<td>GSM</td>
<td>15</td>
</tr>
<tr>
<td>Grønholdt, et. al.</td>
<td>1998</td>
<td>137</td>
<td>GS level</td>
<td>16</td>
</tr>
<tr>
<td>Johnsen, et. al.</td>
<td>2005</td>
<td>1952</td>
<td>GSM, plaque area</td>
<td>17</td>
</tr>
<tr>
<td>Kadoglou, et. al.</td>
<td>2008</td>
<td>149</td>
<td>GSM, hsCRP, WBC, OPN, OPG</td>
<td>18</td>
</tr>
</tbody>
</table>

Future Directions

- 3D Imaging (Madani, et al., 2011)
- Standardization within the field
- Further evaluation of this technique with additional imaging findings
  - Strain
  - TCD

Increased Echolucency of Carotid Plaques in Patients With Type 2 Diabetes

Gösta Ostling, MSc; Be Hedblad, MD, PhD; Göran Berglund, MD, PhD; Isabel Gonçalves, MD, PhD

- N=98
  - N=47 type 2 diabetic
  - N=51 non-diabetic
- Examined plaques in right carotid artery
- Plaque GSM significantly lower in diabetic participants (37±14.8) compared to non-diabetic participants (45.5±15.4), (p=0.007)
- Triglycerides were also significantly associated with plaque echogenicity

Ultrasound plaque grayscale features (GSM, JBA size, percent black area, DWA presence) are associated with histopathologic findings of inflammation, ulceration calcification and hemorrhage. Studies have demonstrated that these features along with clinical history can be used to risk stratify patients. Research studies have demonstrated that these features are associated with CVD risk factors. Potential value as clinical and research surrogates for plaque vulnerability and risk for future event.


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Catherine N. Steffel, MS

References


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References


