Carotid Plaque Characterization and Intima-Media Thickness

Charles H. Tegeler, MD
McKinney-Avant Professor
Vice-Chair, Faculty Development
Founding Director, Telestroke Program
Director, Ward A. Riley Ultrasound Center
Wake Forest School of Medicine
CEA Specimen: ICA Plaque
Carotid Plaque Characterization

- Most Rx decisions made based on Doppler/hemodynamic effect (% stenosis)
- Plaque features can influence decision
- Plaque characterization takes time and attention to detail
- Understanding of principles and adjustments
Carotid Plaque Characterization

- B-mode imaging gives 2-D gray scale image of vessel, wall, plaque, & soft tissue
- Location, size, course of vessels
- Information on plaque features: location, thickness, surface (smooth, irregular, ulcer), texture (homogeneous/heterogeneous), echodensity, and any movement
B-Mode Imaging

- Provides ultrasonic picture of tissues, vessels, plaque (not true anatomic image)
- Best to use ultrasonic terms to describe
- Transducer frequency and focusing determine resolution
- Higher frequency, higher resolution
- Higher frequency, greater attenuation, less working depth
Carotid Plaque Characterization

• Definition of plaque varies
• Absolute thickness
• Protrusion relative to adjacent wall thickness
• Features: Location, thickness, surface, cap thickness, texture, echodensity, motion
## Carotid Plaque Criteria

**WFBMC**

<table>
<thead>
<tr>
<th>Plaque Category</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt; 1.1 mm</td>
</tr>
<tr>
<td>Minimal / Mild</td>
<td>1.1 – 2.0 mm</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.1 – 4.0 mm</td>
</tr>
<tr>
<td>Large / Severe</td>
<td>&gt; 4.0 mm</td>
</tr>
</tbody>
</table>
## Plaque Features

<table>
<thead>
<tr>
<th>Plaque Features</th>
<th>Descriptors / Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Specific vessel segment</td>
</tr>
<tr>
<td></td>
<td>Distribution</td>
</tr>
<tr>
<td>Surface Features</td>
<td>Smooth, Irregular, Crater/Ulcer/Niche</td>
</tr>
<tr>
<td>Texture / Composition</td>
<td>Homogeneous, Heterogeneous/mixed, Possible intraplaque hemorrhage</td>
</tr>
<tr>
<td>Echodensity</td>
<td>Hypechoic, Echogenic, Hyperechoic/dense, +/- shadowing</td>
</tr>
<tr>
<td>Plaque Motion</td>
<td>Radial (normal), longitudinal</td>
</tr>
</tbody>
</table>
Plaque Features:
Smooth and Homogeneous
Irregular Plaque
Calcification/Shadowing
Plaque Features:
Calcification/Shadowing
Plaque Features:
Hypoechoic region/? IPH
Complex Plaque ICA
Thrombosis/Occlusion of ICA
CCA Thrombus in Acute Stroke

Longitudinal

Transverse
Plaque Characteristics

- Suffered from lack of standardized nomenclature and scheme
- Many suggested systems, but pathologic correlations mixed
- More emphasis on hemodynamics, color flow, technical challenges, and time
Plaque Features
Clinical Implications

• Lusby (%/location of hypoechoic regions predict risk)
• Johnson (depth of crater predicts risk)
• Leahy (heterogeneity predicts risk)
• NASCET (ulcer high risk in nonsurgical pt)
• Crater/ulcer less critical independent risk
• Role in stroke risk, esp in less % stenosis
Plaque Features
Lusby Criteria

ULTRASOUND PLAQUE TYPES

Type I
Predominantly echolucent raised lesion, echogenic rim

Type II
Echogenic lesions with substantial areas of echolucency, especially near luminal surface (predominantly echolucent)

Type III
Dominantly echogenic lesions with small areas of echolucency deeply located

Type IV
Uniformly and densely echogenic
Plaque Characteristics

- Unique capability of B-mode ultrasound
- Identifies burden and nature of any atherosclerosis
- Can contribute to understanding of risk, and impact management
- Takes more time and care, but well worth the effort
CCA Intima-Media Thickness
Carotid IMT Definition

• IMT is an acronym often used to refer to the phrase “intima-media thickness”.
• IMT refers to the combined thickness of the intimal and medial layers of the arterial wall.
• Carotid IMT is measured from two-dimensional noninvasive B-mode ultrasound images.
Carotid IMT Definition (Cont’)

Anatomic Basis for IMT

- Histological slices show the intimal and medial layers of two atherosclerotic arteries with \textit{B-mode Carotid IMT Definition} (different plaque characteristics).
- The maximum IMT of each wall is indicated by the vertical yellow line.
- This thickness includes that of both the media (M) and the plaque (P). The plaques affect both the intima and the media.
B-mode Appearance of Interfaces

Pulse duration

Pulse duration
Carotid IMT Protocols

Ultrasound Direction

Skin

ICA  Bifurcation  CCA

ECA
IMT Measurement by Automated Edge Detection IMT Software

1. Sharp interfaces.
2. Correct edge detection.
3. Valid IMT measurement.
IMT Measurement by Automated Edge Detection IMT Software (Cont’)

- Sharp interfaces
- Artifact not present
- Correct edge detection
- Perpendicular to wall
- Valid IMT measurement
1. False edge detection.
2. Measurement line oblique to wall.
3. Invalid IMT measurement!

Operator editing is required for a valid IMT measurement!
Progression of Atherosclerosis
Spectrum of Disease

Focus for IMT Testing

Atherosclerosis

Stable angina
Intermittent claudication

Thrombosis

Unstable angina
MI
Ischemic stroke/TIA
Critical leg ischemia
Cardiovascular death

Clinical Value of Carotid IMT

- Prediction of risk for cardiovascular events using traditional risk factors, such as Framingham Risk Score (ATP-III risk assessment tool), is limited.

- Approximately 50% of cardiovascular events cannot be predicted from traditional risk factors (lipids, blood pressure, smoking, etc.).
Clinical Value of Carotid IMT (Cont’)

- Carotid IMT is an independent predictor of cardiovascular events in general populations after adjustment for traditional risk factors.

- Observational studies have found that for an absolute carotid IMT difference of 0.1 mm, the future risk of MI increases by 10% to 15%, and the stroke risk increases by 13% to 18%.

Adapted from Lorenz MW, et al. Circulation 2007;115
Absolute IMT and Risk of CHD
Atherosclerosis Risk in Communities (ARIC)

- N=12,841
- Age: 45~64 years
- ‘Healthy’, No CVD symptom
- Follow-up: 4~7 years
- Adjusted for age, center and race

Adapted from Chambless LE et al. Am J Epidemiol 1997;146
Absolute IMT and Risk of Stroke
Atherosclerosis Risk in Communities (ARIC)

- N=14,214
- Age: 45~64 years
- ‘Healthy’ without CVD symptom
- Followed-up: 6~9 years
- Adjusted for age, center and race

Adapted from Chambless LE et al. Am J Epidemiol 1997;146
Absolute IMT and Risk of Stroke or MI
Cardiovascular Health Study (CHS)

- N=4,476
- Age: ≥65 years
- ‘Healthy’, No CVD symptom
- Follow-Up: 7 years
- After controlling for age/sex, the odds ratio of MI or stroke was 4.5 for the highest IMT quintile as compared to the lowest quintile
- The possibility of stroke or MI incidence was 4% for the lowest IMT quintile, 26% for the highest quintile
- Compared to other risk factors, IMT was the strongest predictor of stroke or MI

**Absolute IMT and Risk for Stroke (Cont’)**

The Rotterdam Study

- **N=1,683**
- **Age ≥ 55 years**
- **Model 1** - adjusted for age/sex
- **Model 2** - adjusted for age/sex, stroke history, BMI, smoke, SBP, TPC, HDL-C, DM
- With every 0.15 mm increase in Baseline IMT, the 10 year absolute risk for stroke increased by 4.1%

Adapted from Bots et al. Circulation 1997; 96
AstraZeneca Research

- METEOR International Study used CIMT to assess and measure change in the carotid artery of asymptomatic subjects with early atherosclerotic disease and at low CHD risk.
- First study to show positive benefit on atherosclerosis for people with early signs of diseased arteries.
- FDA approved expanded marketing of Crestor based on CIMT data in the METEOR Study (drug halted progression of disease)
- Data showed a 0.0014 mm/yr decrease in the mean maximum carotid intima-media thickness—a marker of atherosclerotic burden, of Crestor patients, compared to a progression of 0.0131 mm/yr for those on placebo.
- The Ward A Riley Ultrasound Center was the Core Reading Laboratory and Ultrasound Training and Quality Control/Quality Assurance Center for the United States as well as an IMT Scanning site for this important pharmaceutical trial.
Change in Maximum Carotid Intima-Media Thickness (CIMT) for the Primary End Point

Carotid IMT

- Precise, computer assisted measurements of carotid wall thickness (IMT) are associated with risk factors
- IMT predicts cardiovascular risk
- Used as surrogate for atherosclerosis and clinical endpoints
- Assess IMT given age, race, gender to predict CV risk – translate to clinical realm
- Devil in the details for protocol and reading
Table 1. Far Wall IMT Measurements

<table>
<thead>
<tr>
<th>Arterial Site</th>
<th>Far Wall IMT</th>
<th>80% Prediction Interval</th>
<th>Far Wall Percentile</th>
<th>80% Prediction Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>(Lower, Upper)</td>
<td>Observed</td>
<td>(Lower, Upper)</td>
</tr>
<tr>
<td>Left Bifurcation</td>
<td>0.98 mm</td>
<td>(0.76,1.2)</td>
<td>92 %</td>
<td>(75,99)</td>
</tr>
<tr>
<td>Left Common</td>
<td>1.06 mm</td>
<td>(0.84,1.27)</td>
<td>99 %</td>
<td>(96,99)</td>
</tr>
<tr>
<td>Left Internal</td>
<td>0.69 mm</td>
<td>(0.52,0.86)</td>
<td>79 %</td>
<td>(41,92)</td>
</tr>
<tr>
<td>Right Bifurcation</td>
<td>2.04 mm</td>
<td>(1.36,2.71)</td>
<td>99 %</td>
<td>(98,99)</td>
</tr>
<tr>
<td>Right Common</td>
<td>0.84 mm</td>
<td>(0.73,0.95)</td>
<td>99 %</td>
<td>(89,99)</td>
</tr>
<tr>
<td>Right Internal</td>
<td>0.87 mm</td>
<td>(0.64,1.1)</td>
<td>87 %</td>
<td>(67,93)</td>
</tr>
<tr>
<td>Average</td>
<td>1.08 mm</td>
<td></td>
<td>93 %</td>
<td></td>
</tr>
</tbody>
</table>

1 Percentiles:
Percentiles are based on individuals of similar age, gender and ethnicity from the Atherosclerosis Risk in Communities (ARIC) Study (ref: Stroke 1993:24:1297-1304). Percentiles greater than 50 are associated with thicker IMT and greater risk. Percentiles less than 50 imply thinner IMT and lower risk.

2 Prediction Intervals:
Prediction Intervals describe uncertainty in IMT measurements. If a large number of repeat examinations were performed, we would expect 4 of every 5 new measurements to fall within the interval shown for each arterial site.
Risk Assessment:
Your relative risk for CHD is 2.17, based on your average far wall percentile score and data from 4-7 years of follow-up in the ARIC Study (Am J Epi 1997;146:483-494). A relative risk of 2.17 means that you are 117% more likely to develop heart disease than other people of similar age, gender and ethnicity.

Presence of plaque ≥ 2 mm suggests increased cardiovascular risk independent of IMT results.

Plaque ≥ 2 mm identified?
☐ No ☑ Yes (see comment below)

Physician Notes:
Large plaque was seen in the right S1 FTA region (4.8 mm, far wall). No hemodynamically important stenosis was seen.

I have personally reviewed the CIMT results and agree with the interpretation.

Reviewing Physician: [Signature] Date: 1/15/12
Charles H. Tögele, M.D.
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Bifurcation</td>
<td>0.71 mm</td>
<td>(0.56,0.87)</td>
<td>51 %</td>
</tr>
<tr>
<td>Left Common</td>
<td>0.53 mm</td>
<td>(0.45,0.6)</td>
<td>26 %</td>
</tr>
<tr>
<td>Left Internal</td>
<td>0.6 mm</td>
<td>(0.45,0.74)</td>
<td>57 %</td>
</tr>
<tr>
<td>Right Bifurcation</td>
<td>0.72 mm</td>
<td>(0.55,0.88)</td>
<td>49 %</td>
</tr>
<tr>
<td>Right Common</td>
<td>0.53 mm</td>
<td>(0.45,0.6)</td>
<td>25 %</td>
</tr>
<tr>
<td>Right Internal</td>
<td>0.5 mm</td>
<td>(0.37,0.63)</td>
<td>28 %</td>
</tr>
<tr>
<td>Average</td>
<td>0.6 mm</td>
<td></td>
<td>39 %</td>
</tr>
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1 Percentiles:
Percentiles are based on individuals of similar age, gender and ethnicity from the Atherosclerosis Risk in Communities (ARIC) Study (ref: Stroke 1993:24:1297-1304). Percentiles greater than 50 are associated with thicker IMT and greater risk. Percentiles less than 50 imply thinner IMT and lower risk.

2 Prediction Intervals:
Prediction Intervals describe uncertainty in IMT measurements. If a large number of repeat examinations were performed, we would expect 4 of every 5 new measurements to fall within the interval shown for each arterial site.
**Risk Assessment:**
Your relative risk for CHD is 0.86, based on your average far wall percentile score and data from 4-7 years of follow-up in the ARIC Study (Am J Epi 1997:146:483-494). A relative risk of 0.86 means that you are 14% less likely to develop heart disease than other people of similar age, gender and ethnicity.

Presence of plaque ≥ 2 mm suggests increased cardiovascular risk independent of IMT results.

**Plaque ≥ 2 mm identified?**  
☒ No  ☑ Yes (see comment below)

**Physician Notes:**

I have personally reviewed the CIMT results and agree with the interpretation.

**Reviewing Physician:**  
Charles H. Tegeler, M.D.  
**Date:** 2/8/12