Plaque Imaging:
What It Can Tell Us

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Buffalo Disclosure Information

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Cerebrovascular Disease

- Fourth leading cause of death in the U.S. and second worldwide.
- Approximately 800,000 people experience a new or recurrent stroke in the U.S each year.
- The direct and indirect cost of stroke in 2007 was 40.9 billion.

- Heart Disease and Stroke Statistics 2012
Classification of Stroke

• Ischemic (80%)
  • ICAD
  • Lacunar
  • Carotid Occlusive disease (25%)

• Hemorrhagic (20%)
  - Intracerebral hemorrhage
  - Subarachnoid hemorrhage
What is the Clinical Significance?

• Silent hits on MRI?
  • If Carotid is greater than 50% stenosed on that side do you consider this a Sx ICA?

• Hemorrhage within a Carotid Plaque and Greater than 50% stenosis?
  • If pt has no clinical symptoms is the pt at higher risk?
  • And what is best treatment method for “hot Plaque”
Timing of Stroke After Carotid Revascularization: CAS vs. CEA

P = 0.0008**

Circulation 2012;126:3054-3061
CAS and Day 0 Strokes

- CAS is struggling with understanding why our day 0 periprocedural stroke rate is higher than CEA
- Does Plaque morphology play a part?
  - Direct Plaque Imaging with MRI may help us answer this
  - Is standard distal protection enough?
  - I will show IVUS imaging of significant “Snow Plowing” of hot plaque through Wall stents
  - Should all these be done with prox protection and IVUS?
MRI and MRA of the Carotid Arteries
MRI of the CAROTID ARTERIES

• Review Pathogenesis/Progression

• Plaque Constituents
  • Morphology
    • Stable vs Unstable (Vulnerable)

• Survey of Methods and Results
  • Most Published Results - 1.5T

• Recent 3T Carotid MRI Studies
ATHERTOSCLEROSIS

- Intimal Disease
- Inflammatory Disease
- Response of the Intima to Injury


Davies, MJ, Woolf, N. “Atherosclerosis: what it is and why does it occur?. Br Heart J; 1993: 69;S 3-11
ARTERIAL PLAQUE COMPOSITION

• Major Components
  • Lipids
    • Lipid-Containing “Foam Cells” (Macrophages)
    • Macrophages
  • Connective Tissue
    • Matrix Proteins - Collagen
    • Strengthens, Holds Plaque Together
  • Other Components
    • Calcification
ATHEROGENESIS
Endothelial Injury/Dysfunction

Immune/Inflammatory Response
- Increased Adhesiveness
- Increased Permeability
- Procoagulant Properties
- Release of Growth Factors

Thickening of Artery Wall and “Remodeling”
ATHEROGENESIS
Plaque Formation

• Modified Lipids Migrate Into Intima
• Ingested by Macrophages
  • Uptake is Unregulated
    “Foam Cells”

Smooth Muscle
Proliferation and Migration
Release of Growth Factors
ATHEROGENESIS
Unstable (Vulnerable) Plaque

Necrotic Lipid Core Grows Large
Fibrous Cap Wears Thin - Ruptures Thrombus
CAROTID IMAGING

MRI vs US

Little MRA - Mostly MRI

- Soft Tissue Contrast
  - Lipid, Smooth Muscle, Fibrous Tissue

- MR Signal Independent of Angle

- Flow Sensitive
  - Simultaneous Information on:
    - Vessel Lumen
    - Vessel Wall
FSE Black Blood Imaging

Double Inversion Black Blood Sequence

\[ TI_{\text{null}} = T1 \times \ln \left( \frac{1 + e^{\frac{TR}{T1}}}{2} \right) \]
T2-W FSE (Dark Blood)
1.5T MRI STUDIES

- Multiple Weightings – T2W, T1W, PDW

- Fibrous Cap Thickness Measurement

- Contrast Enhanced
MRI of CAROTID PLAQUES

- T2-Weighting
- Delineates Lipid Core and Thrombus

Figure 1. Multisequence (ToF, T1, PD, and T2) appearance of a stable, concentric fibrolipomatous plaque in a left CCA shown adjacent to the matched histology section. An intact, hypointense juxtaluminal band seen in the ToF image (black arrows) correlates with a subendothelial region of fibrous tissue that is not readily discernable in the T1-, PD-, or T2-weighted sequences.
Magnetic Resonance Imaging (MRI) of Carotid Plaques

- Lipid Core/Fibrous Cap

Mallory’s Trichrome

Figure 4. Example of a luminal contour abnormality. A focal concavity of the luminal surface (arrowhead), best depicted on the ToF and T1 images, correlates with an unstable, ruptured cap on the corresponding histologic section.
Calcification

Mitsumori, L, et al. JMRI 2003 17:410-420

Figure 6. Utility of multisequence imaging in the presence of intimal calcifications. In the ToF image the hypointense juxtaluminal band, which is associated with the fibrous cap, is obscured (black arrow) by amorphous regions of low signal created by large intimal calcifications (labeled and outlined on the histology section). Intimal tissue present between these calcifications and the lumen is visible as an area of increased signal (white arrows) in the T1, PD, and T2 images.
MRI of CAROTID PLAQUES

- **3D TOF (Bright Blood)**
  - Bright Lumen/Dark Fibrous Tissue
  - Identify Unstable Fibrous Caps in vivo

- **Imaging Parameters:**
  - TR = 23 ms
  - TE = 3.8 ms
  - 2 Signal Averages
  - Scan Time = 2 - 4 Min.
MRI of CAROTID PLAQUES

- 3D TOF (Bright Blood)
- Spatial Resolution
  - Slice Thickness = 2 mm
  - Acquisition Matrix:
    - Size = 256 x 256
    - Voxel Size = 0.5 x 0.5 x 2 mm
- Zero Filled:
  - Matrix = 512 x 512
  - Zero Filled Voxel Size = 0.25 x 0.25 x 2 mm
MRI of CAROTID PLAQUES

- Unstable Fibrous Cap Detection

MRI of CAROTID PLAQUES

• Identify Stable/Unstable Plaques

• Follow Progression of Plaque Development

• Monitor Therapies
CONCLUSIONS

• 3.0 Tesla MRI Offers Improved Signal-to-Noise Ratio – Resolution

• IMT Measurements

• May Be Able To Identify Unstable Plaques
  • Improved Accuracy: Measurement Cap Thickness

• May Improve Monitoring of Interventional Therapies
We analyzed carotid stenosis patients from July 2010 – Dec 2010 with carotid stenosis who underwent 3.0 T MRA plaque morphology for carotid diseases.

We grouped patients into high risk patients (intra plaque hemorrhage, necrotic lipid core and thin fibrous cap).

In 6 months A total of 33 patients underwent 3.0T-MRA imaging of the carotid arteries.
Plaque morphology of the left carotid demonstrates the plaque with the hypodense necrotic core (*)

The plaque demonstrates a hyperintense signal indicating hemorrhagic conversion (**)
Among symptomatic patients with high-risk-MRA only (2/5, 40%) had significant stenosis, they 2/5 (40%) underwent CAS with proximal protection.

1/10 (10%) with low-risk-plaque feature underwent CAS (distal protection).

One patient with high-risk features on MRA underwent CAS with proximal protection experienced dysphasia and was treated with IV epifibitide.
Conclusions

• MRA plaque morphology can be invaluable while selecting the protection device (proximal protection vs distal protection).

• Our study has shown that by careful selection of patients based on plaque morphology the perioperative stroke rate could be minimized.
IVUS detected thrombus

“hot plaque”
treated with Proximal Protection
Thank You!