Neuroradiology of Acute Stroke

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Background

• Stroke is the third leading cause of death in the US, behind heart disease and cancer
• Stroke is the leading cause of severe long-term disability
• US stroke costs now exceed 63 billion dollars per year
• 87% of strokes are ischemic
• Intracranial atherosclerosis responsible for 70,000 ischemic strokes each year

Multimodal CT and MR: Goals of Emergent Evaluation of Acute Stroke

- Establish vascular etiology of neurologic deficit
- Rule-out stroke mimics
- Differentiate hemorrhagic from ischemic stroke
- Determine etiology or mechanism of the event
- Assess reversibility and eligibility for acute therapies
- Determine efficacy of Rx
- Provide early prognostic information

Lecture Outline

- CT – early and late infarct signs- clinical implications
- Monitoring of stroke complications
- CT perfusion
  - The infarct core
  - The ischemic penumbra
  - CT perfusion cerebrovascular reserve
  - risk of hemorrhagic transformation
- CTA/CTP– clinical examples
- CTA vs. MRA
- Utility of DWI, ADC
- Perfusion imaging
- Clinical examples
- Role of microbleeds
- NINDS Trials
- Time resolved MRA
- New techniques
- Conclusions

Noncontrast CT and MR with DWI– Sensitivity for Acute Stroke

<table>
<thead>
<tr>
<th>Study</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>P-value</th>
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<tbody>
<tr>
<td>CT with suspicion</td>
<td>52%</td>
<td>95%</td>
<td>p=0.008</td>
</tr>
<tr>
<td>CT without suspicion</td>
<td>38%</td>
<td>89%</td>
<td></td>
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<tr>
<td>MR with suspicion</td>
<td>95%</td>
<td>94%</td>
<td>p=0.822</td>
</tr>
<tr>
<td>MR without suspicion</td>
<td>94%</td>
<td>96%</td>
<td></td>
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</table>

AJR. 2002;179:223-229 (n=733)

Multimodal CT (Noncontrast CT, CTA, CTP) – Rationale In Hyperacute Stroke

- MRI not feasible in up to 20% of acute stroke patients*
  - Level of consciousness, agitated, vomiting
  - Hemodynamically compromised (73% ICH)
- NECT, PCT and CTA provide diagnostic and therapeutic information <15 mins, with results comparable to MR**
- Most small and medium sized hospitals do not offer MR 24/7

Case #1

• 40 yo WM presents at 1 hour after symptom onset with left hemiplegia and neglect
• PMH: HTN, Paroxysmal Atrial Fibrillation, Hypercholesterolemia
• Medications: Coumadin, Enalapril, Zocor

Case Discussion – Late Infarct Signs

• Finding
  – Hypodensity throughout MCA territory – findings inconsistent with onset time
  – Hyperdense MCA Sign
• Clinical Consequence
  – History retaken – onset time clarified – patient actually last known well 5 hours prior to CT
  – Large MCA territory completed infarct
  – Therefore, IV tPA not given
  – Anticipate poor functional recovery

Case #2

• 66 yo WM presents at 2 hours after sudden onset of right hemiparesis and global aphasia
Case Discussion - Early Infarct Signs

- **Finding:**
  - Loss of gray-white differentiation
  - Sulcal Effacement
  - No hemorrhage

- **Relevant Data:**
  - In NINDS trials, early infarct signs not an exclusion criterion; patients with early infarct signs benefited from therapy

- **Clinical Consequence**
  - Patient treated with IV rt-PA with improvement in NIHSS score from 14 to 3 at day 7

Current AHA Guidelines: Early CT Infarct Signs

- Patients with early infarct signs on CT (even if they involve greater than 1/3 of the middle cerebral artery territory) and with a well established stroke onset time < 3 hours are candidates for treatment with IV rtPA and may have a favorable response to thrombolytic therapy.

AHA Guidelines: Early CT Infarct Signs

- There are insufficient data to make a strong recommendation regarding the use of IV rt-PA treatment in the rare patient whose CT reveals extensive and clearly identifiable hypodensity yet show a well established stroke ictus onset time < 3 hours.

- While differences of opinion exist, we recommend that thrombolytic therapy not be administered in these patients because a possible unfavorable risk/benefit ratio.

CT Monitoring of Stroke Complications

- Hemorrhagic transformation
- Hemicraniectomy for malignant cerebral edema

Multimodal CT - Ischemia, Acute Stroke and Completed Stroke: NECT, CTA and CT Perfusion

- NECT
- PCT
- CTA

Case #3

- 39 yo RH WM with history of hyperlipidemia presents with recurrent episodes of left hemiparesis while therapeutic on warfarin therapy
- CT and MR negative for ischemia or infarct
Imaging Findings - CTA

Sensitivity and PPV of CTA for intracranial stenosis (98% v. 70%) and occlusion (100% v. 67%) is higher than 1.5T 3D TOF-MRA using DSA as gold standard


CT Perfusion Time Density Curve

MTT (sec)

CBF = CBV / MTT

HU

CBF (cc/100g/min)

CBV (cc/100g)

Dynamic Perfusion CT - Findings

Infarct core and The Ischemic Penumbra

The Internet Stroke Center

CTP-rCBV and Hyperintensity on MR Diffusion Imaging – Reflect Tissue Ischemia and the Resultant Arrest of the Na-K ATP-ase Pump with Impaired Cytosolic Brownian Motion

Meir & Zieler, J Appl Physiol, 1954

Thresholds for Ischemia -varies depending on size, duration and adequacy of collaterals

- Oligemia = < 40-60 cc/100g/min for whole brain (white and gray) and normal CBV
- Ischemia = 20-30 cc/100g/min Plus elevated CBV
- Infarction = <20 cc/100g/min and decreased (collapsed) CBV
The Ischemic Penumbra

<table>
<thead>
<tr>
<th>Tissue type</th>
<th>CBF</th>
<th>CBV</th>
<th>MTT</th>
<th>Tissue State</th>
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<tbody>
<tr>
<td>Normal tissue</td>
<td></td>
<td></td>
<td></td>
<td>Normal</td>
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<tr>
<td>Viable, oligemic</td>
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<td>↑</td>
<td>↑</td>
<td>Penumbral</td>
</tr>
<tr>
<td>Viable, ischemic</td>
<td>↓↓</td>
<td>↑</td>
<td>↑</td>
<td>Infarct Core</td>
</tr>
<tr>
<td>Infarct – bland</td>
<td></td>
<td></td>
<td></td>
<td>Infarct Core</td>
</tr>
<tr>
<td>Infarct, reperfused</td>
<td>↑↑</td>
<td>↑</td>
<td>↓</td>
<td>Infarct Core</td>
</tr>
</tbody>
</table>


Lack of Cerebrovascular Reserve – Left MCA Territory

Case Discussion:

Hypoperfusion and Impaired Cerebrovascular Reserve

- Finding
  - CTA: 83% MCA stenosis
  - Perfusion CT: resting perfusion deficit in MCA territory worsened following Diamox
  - Indicates impaired cerebrovascular reserve
- Clinical Consequence
  - Pt treated with flornof for hemodynamic events with resolution of symptoms
  - Patient started on Aspirin
  - Consider intracranial to extracranial arterial (EC-IC) bypass to augment cerebral blood flow to left MCA territory

Case #4

- 55 yo WM 24 hours post thrombolysis for left MCA occlusion on “triple H” therapy.

Aspirin should be used in preference to Warfarin for patients with intracranial stenosis. The WASID Trial. NEJM 2005;352:1305-1316 (n=569)
The Role of CT Perfusion Post Thrombolysis

Slice from 4 slice study of CTP in patient 24 hrs post lysis of left MCA clot.

Loss of Autoregulatory Control in Reperfused Infarct Zone - CT Hyperperfusion

CT and Perfusion CT scan performed 24 hr after thrombolysis for left MCA occlusion.

Source image CBF
CBV MTT

Case Discussion: Risk of Hemorrhagic Transformation

• Finding
  – NCT: Small established infarct, MCA branch
  – Perfusion CT:
    – Flow re-established to most of left MCA territory.
    – Recanalization in area of completed branch MCA infarction with luxury perfusion.
• Clinical Consequence
  – Consider stopping hypervolemic, hypertensive therapy to avoid potentiation of hemorrhagic transformation and reperfusion injury.

Detection Power of Perfusion CT

<table>
<thead>
<tr>
<th>Author</th>
<th>Territorial infarcts</th>
<th>Non-territorial infarcts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity</td>
<td>Specificity</td>
</tr>
<tr>
<td>Maruya, 2005</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Mayer, 2000</td>
<td>93%</td>
<td>–</td>
</tr>
</tbody>
</table>

CT Perfusion – The Literature

• “CT Perfusion is accurate and reliable as compared to Xenon-CT”
• “When compared to diffusion-perfusion MR, CT has been shown to be equivalent in identifying the ischemic penumbra in patients with acute stroke”

Utility of CT Perfusion (PW-CT) in Acute MCA Stroke Treated with IA-Thrombolysis

• Lesion volumes on PWCT images approximate final infarct volumes for patients with early complete recanalization of MCA stem occlusion treated within 6 hours of symptom onset
  – Infarct volumes >100 mL were associated with poor clinical outcome.
  – PW-CT lesion volume was a stronger predictor of clinical outcome than initial NIH stroke scale score.

Stroke 2001;32:2021-2028 (n=22)
CT Perfusion – Whole Brain Volume and Arterial Circulation

Uses of Multimodal MD-CT in the Acute Stroke Patient

- Tandem stenosis
- Nonatherosclerotic stenosis
- Progressive stenosis, plaque and ulcers
- Dissection
- Re-stenosis post-stent
- Fibromuscular dysplasia

CTA in Tandem stenosis

Non-atherosclerotic causes of arterial stenosis

Uncovertebral Joint osteophyte

1/7/03 1/29/04
CTA and DSA – Ulcer Crater

CTA and Carotid Ulcer – Cine 2D

Helical CTA – Arterial Dissection

CTA shows 100% sensitivity for carotid dissection

Pelkonen D. Acta Radiol. 2004;45:259-265

CTA in Carotid dissection:
Axial 2D MPR – Cine mode

1. Occlusion after dissection associated with stroke in 76%, most embolic.
2. Stroke follows dissection in 56%

Pelkonen D. Acta Radiol. 2004;45:259-265

70% of dissections heal spontaneously

Desfontaines P. Acta Neurol Belg. 1990;90:225-234

Dissection causes 1-4.2.5% of all strokes and 5-20% of stroke in young

Provenzale J.M. AJR 1995;165:1099-1104

CTA in Acute Carotid Dissection with complete occlusion – arterial caliber is preserved

Wall Thrombus
**Case Discussion – Arterial Dissection**

- **Findings** – Multivessel dissection
  - Tapering stenoses of bilateral carotids with left crescent sign on axial T1 scan and intimal flap on CTA
  - Left vertebral artery pouch / pseudoaneurysm on CE-MRA and 3D-CTA
- **Clinical Consequence**
  - Anticoagulation therapy initiated
- **Comments**
  - Thromboembolism, not hemodynamic compromise, may be the essential stroke mechanism in carotid dissection


**Fibromuscular Dysplasia**

- **No definitive literature on sensitivity and specificity of CTA for FMD.**
- **String of beads appearance**
- **ICA, 2nd most common site**
- **Type I, 80-85% - segmental beading**
- **Type II, 6-12% - long tubular**
- **Type III, 4-6% - one side of artery**
- **DSA and CTA unable to differentiate between intimal, medial and subadventitial types**
- **Ischemia 20%, TIA 30%, thromboembolic stroke 6%, dissection 10-20%**
- **33% also have renal FMD**

**Benefits of CTA vs. 1.5T Time-of-Flight MRA**

- Nonluminal information – soft and hard plaque.
- Higher spatial resolution
- Facilitates accurate quantitation
- Visualization of patent lumen in severe stenosis or very slow flow.
- Identification of incidental lesions with high resolution

**CTA Limitations**

- No hemodynamic information
- Simultaneous arterial and venous imaging
- Lower spatial resolution than DSA
- Post-processing required
- Contrast allergy
- Radiation
Multimodal MRI: Acute Stroke Treatment Decision Making – Breaking the Time Barrier

Stroke Protocol: T1W, T2W, FLAIR, GRE, DWI, ADC, MRA Neck and Brain and Perfusion MR

Signal Intensity of Diseased Tissue Relative to Normal Tissue

<table>
<thead>
<tr>
<th>Tissue state</th>
<th>DWI</th>
<th>ADC</th>
<th>T2W</th>
<th>FLAIR</th>
<th>T1W</th>
<th>PWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemia</td>
<td>↑</td>
<td>↓</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Infarction</td>
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<tr>
<td>Edema</td>
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<tr>
<td>Gliosis</td>
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<td></td>
<td></td>
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<tr>
<td>Encephalomalacia</td>
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</tbody>
</table>

Note: Colored arrows denote key differentiators

Clinical Utility of DWI and ADC

- Confirm acute ischemic event (DWI bright)
- Use ADC to exclude T2W shine through effect since DWI is T2 based but ADC is not
- Rule-out stroke mimics (Todd’s paralysis and tumors)
- Identify new lesion in setting of old disease
- Identify stroke mechanism
  - Proximal embolic source
  - Small vessel
  - Large vessel
  - Watershed
  - Vasculitis as a mechanism? Need DSA!

Clinical Utility of T2W and FLAIR Sequences in DWI-Based Stroke Evaluation

- Differentiate between:
  - acute ischemia (ischemic but viable brain tissue) = normal T2W and FLAIR
  - completed cerebral infarction (tissue death) = high T2W signal and low on T1W and FLAIR

Case #5

- 82 yo HF without known vascular risk factors found at home with confusion, incontinence, and right sided hemiparesis which improves significantly in emergency department
- Differential Diagnosis
  - Seizure with Todd’s paralysis
  - Stroke
Imaging Findings – DWI hyperintense, ADC hypointense, FLAIR and T2W hyperintense

Case Discussion – Stroke Mimics
• Finding
  – Left thalamic infarct not clearly visualized on CT, confirmed on DWI and T2W
• Clinical Consequence
  – Confirmation of ischemic event
  – Appropriate work-up for stroke rather than seizure initiated
• Comments
  – DWI is clinically useful up to several weeks after stroke*


Diffusion Imaging and TIA’s
• Aggregate data from 7 observational studies: almost 1/2 of patients with clinical TIA syndromes have a DWI abnormality
• The likelihood of DWI positivity increases with increasing symptom duration
• Although lesions may resolve in some, the majority of patients have imaging evidence of permanent ischemic injury, even if clinically silent.

MRI and Early Hemorrhage Evaluation (GRE,SWI)

Case #6
• 54 yo African American male presents 30 minutes after sudden onset of left-sided weakness
• PMH: Poorly controlled hypertension
• Medications: HCTZ
• Exam: BP 220/110, left hemiplegia and hemisensory loss

Imaging Findings

NECT MRI GRE MRI SWI
Case Discussion- Parenchymal Bleeding

HEME and German Collaborative Studies

• MRI, including GRE appears to be as accurate as CT in detecting hyperacute ICH >1 and < 6 hrs.

• MRI may be employed as the sole imaging study for evaluation of acute stroke patients (ie, CT no longer required to rule out parenchymal hemorrhage)*


Case #7

• 60 yo WM presents 3 hours after onset of right sided weakness and clumsiness

• PMH: HTN and DM

• Medications: Vasotec, Insulin, ASA

Imaging Findings CT and MR

- CT
- DWI
- ADC
- TTP

T2W and FLAIR images normal

Dynamic MR Perfusion (PWI)

*MTT values obtained by PWI are a reliable parameter of cerebral hemodynamics, but CBF and CBV are not always reliable vs. 15O-PET**


Results of the NINDS Study: Odds Ratio for Favorable Outcome at 3 months in IV rt-PA vs. placebo by Time of Stroke Onset compared to Placebo

Values adjusted for baseline NIH stroke scale (n=2,775)

OTT = onset to treatment time


Recanalization Status in Patients with and without Thrombolysis (IV rt-PA)

<table>
<thead>
<tr>
<th>TIM 0</th>
<th>TIM 1</th>
<th>TIM 2</th>
<th>TIM 3</th>
<th>TIM 4</th>
<th>TIM 5</th>
</tr>
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<tbody>
<tr>
<td>17</td>
<td>30</td>
<td>17</td>
<td>20</td>
<td>11</td>
<td>0</td>
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</table>

The Thrombolysis in Myocardial Infarction (TIMI) Score was defined as: 0=no perfusion, 1=perfusion past the initial occlusion but no distal branch filling, 2=perfusion and incomplete or slow distal branch filling, or 3=full perfusion with filling of all distal branches.

On average only 40-50% of MCA stroke patients experience partial or complete recanalization.


**What is the role of imaging in the 3-6 hour time window?**

- Meta-analyses suggest information about the presence or absence of a vessel occlusion, whether by means of CTA, or MRA, is essential before recombinant tissue plasminogen activator is given in the 3- to 6-hour time window. Clear demarcation of the ischemic penumbra as seen on DWI/PWI/MRA or alternatively CT/CTA/CTP should be obtained before thrombolysis is initiated within 3 to 6 hours. Once these advanced techniques are used, the therapeutic time window can be extended with acceptable safety.
- Assumes imaging shows no evidence of completed infarction and a significant diffusion perfusion mismatch
- ECAS 3 study just completed in Europe suggests IV rt-PA safe up to 4.5 hours post infarct

Stroke 2003;34:575-583

**Imaging Findings**

- MR Imaging Findings -GRE

**Case Discussion- Microbleeding**

HEME and German Collaborative Studies

- MRI is superior to CT in detecting chronic hemorrhage including microbleeds *
- Microbleeding may increase the risk of hemorrhage in IV thrombolysis patients *
- Occur more frequently in patients with recurrent stroke **
- The role of microbleeds in thrombolytic decision making needs further study, but at this time microbleeds are a relative contraindication to IV rt-PA

Case #8

- 68 yo WM presents with recurrent dizziness and dysarthria following right arm exercise.
- PMH: CAD, HTN
- Medications: Aspirin, atenolol

Analysis of Time Resolved 3.0T CE-MRA
Right Subclavian Steal

Temp resolution 1.5s, In-plane resolution: 1 x 1.3mm², at 3.0T using GRAPPA x 3

3.0 CE-MRA vs. DSA: Rt. MCA Stenosis

3.0T MR Perfusion with Quantitative Analysis using Phase Contrast (PC) MRI

3.0T CE-MRA: Dynamic Study - Left Temporal AVM

Dynamic CE-MRA Cerebral AVM
Case #9

- 75 yo female with known vascular dementia and multiple medical problems brought to emergency room with confusion question of new left sided weakness per nursing home staff
- Baseline labs reveal UTI
- Differential Diagnosis
  - New stroke
  - Unmasking of old deficit due to UTI

Imaging Findings

Case Discussion – Small Vessel

- Finding
  - DWI reveals new ischemic event in setting of severe leukoariosis
- Clinical Consequence
  - Antithrombotic regimen adjusted

Case #10

- 63 yo WF with multiple medical problems admitted to hospital for progressive altered mental status
- Neurologic exam: patient unresponsive

Imaging Findings

Case Discussion – Large Vessel

- Finding
  - Multiple DWI positive lesions not visualized on CT demonstrated throughout multiple vascular territories indicating proximal embolic source likely mechanism
- Clinical Consequence
  - Work-up for embolic etiology (TEE) revealed valvular vegetations
  - Patient treated for septic emboli
Case #11

- 59 yo WM with history of hypertension, hyperlipidemia, and peripheral vascular disease presents with 5 transient, stereotyped episodes of left hemiparesis lasting 5-15 minutes

Case Discussion - Watershed

- Finding
  - Right ACA – MCA watershed territory infarcts and right ICA occlusion
- Clinical Consequence
  - Patient treated with hypertensive/hypervolemic therapy with resolution of symptoms
  - Consideration of EC-IC bypass

Case #12

- 29 year old female presents 1 week post-partum with severe headaches; in the emergency room she has a generalized tonic-clonic seizure
Bone Subtracted CT Venography

Case Discussion – Venous Ischemia and Infarction

- Finding
  - Empty delta sign on contrast CT
  - Sagittal sinus thrombosis on MRV
- Clinical Consequence
  - Anticoagulation initiated
- Comments – deterioration on anticoagulation
  - There is currently no available evidence from randomized controlled trials regarding the efficacy or safety of thromolytic therapy in this setting*


Coronal MIP from 3D MR angiography (TR/TE: 3/1 ms, FA: 60°, BW: 350Hz/Pixel, GRAPPA x4) shows entire supra-aortic arteries. Voxel dimension of 0.7 x 0.6 x 0.8 mm³, during 20 seconds breath-hold after intravenous injection of 20ml contrast. (b) Sagittal MIP from 3D cerebral venography (TR/TE: 3.4/1.4 ms, FA: 20°, BW: 620Hz/Pixels, GRAPPA x6) acquired immediately after MRA, following the same contrast injection. The entire data was acquired with voxel dimension of 0.7 x 0.7 x 0.8 mm³ during 24 seconds. Note Isotropic voxels

3.0T Single injection CE-MRA and CE-MRV

3.0T CE-MRV – Dural Fistula

Case #13

- 40 yo WM without significant PMH presents with 2 day history of neck pain, headache, and recurrent episodes of transient right sided weakness

Imaging Findings – CE-MRA / T1W
Case #14

- 55 year old RH WM with history of HTN, 5.5 hours after sudden onset of left hemiparesis and hemisensory loss

Multi MERCI Trial (2008) (n=168)
Extended therapeutic window of up to 8 hours
Revascularization rates of 68%, and favorable outcome (mRS<2) in 36% of patients device plus adjuvant therapy. 34% mortality at 90d

Acute MR Imaging Findings

DWI | PWI
---|---
Pre-treatment | Early Positive T2W and FLAIR
5.5 hrs | 
Post-treatment | Positive T2W and FLAIR
18 hrs |

Discussion - Infarct of Ischemic Core

- Finding
  - Large late diffusion-perfusion mismatch

- Clinical Consequence
  - Pt treated with clot retriever with recanalization and symptom resolution
  - Small ischemic core undergoes infarction

Mismatch Model: Ischemic Penumbra

- DWI Abnormality: Bioenergetic Compromise = Core
- Perfusion Abnormality: Hemodynamic Compromise
- Diffusion/Perfusion Mismatch = Penumbra

Alternate Tissue Fate – Complete DWI Reversal

DWI | ADC | PWI
---|---|---
Pre-Lysis |  |  |
Post-Lysis |  |  |

19

**Modified View of Ischemic Penumbra**

**Fate 1: Sustained Reversal**


<table>
<thead>
<tr>
<th>Pre-Thrombolysis</th>
<th>Post-Thrombolysis</th>
<th>Day 7</th>
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<tbody>
<tr>
<td>DWI</td>
<td>ADC</td>
<td>T2</td>
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**Fate 2: Late Secondary Injury**


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<th>Pre-Thrombolysis</th>
<th>Post-Thrombolysis</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWI</td>
<td>ADC</td>
<td>T2</td>
</tr>
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</table>

**Multivariate Analysis: Initial Radiologic Characteristics and Favorable Outcome**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>CI (95%)</th>
<th>P-value</th>
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<tbody>
<tr>
<td>Early ischemic change &gt;1/3 major vascular territory</td>
<td>0.7</td>
<td>0.1-3.5</td>
<td>0.66</td>
</tr>
<tr>
<td>Carotid T v. MCA</td>
<td>0.2</td>
<td>0.02-1.6</td>
<td>0.12</td>
</tr>
<tr>
<td>MCA: ICA</td>
<td>5.5</td>
<td>1.3-26.7</td>
<td>0.02</td>
</tr>
<tr>
<td>Successful (TIMI) recanalization</td>
<td>1.9</td>
<td>0.5-6.6</td>
<td>0.27</td>
</tr>
<tr>
<td>Age/Sex</td>
<td>0.7/1.6</td>
<td>0.2-2.3</td>
<td>0.52/0.09</td>
</tr>
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**IA Therapy and the Role of Multimodal MRI**

- Identify Ischemic Penumbra
- Identify Increased Risk of ICH
- Monitor Response to Therapy
- Optimize Therapy

**Emerging From Stroke – Functional Recovery**
Conclusions – Stroke = Brain Attack!

- Time is brain! Education is key!
- Multimodal CT and MR are powerful tools in the evaluation of neurologic and neurovascular disease.
- The perfusion state of the brain tissue as defined by MR and CT may be a more clinically useful way to determine tissue viability than time from symptom onset.
- Strategies in which patients are scanned immediately cost less and achieve the most quality-adjusted life years vs. the cost of hospital and societal care without imaging.