Update on Imaging of Stroke

William P. Dillon, M.D.
Professor of Radiology
UCSF Radiology and Biomedical Imaging

I have nothing to declare

Goals of Stroke Imaging

- Is stroke or ischemia present?
  - Hemorrhage +/-
  - Infarction vs other diseases

- Timing of stroke
  - Is the treatment window open?

- Treatment options
  - IV tPA
  - Embolectomy, endarterectomy
  - Other options?

Is there a stroke present?
hemorrhage /bland infarction: CT
Infarction vs other diseases: MR

- CT
  - Non Contrast CT
  - CT perfusion
  - CT Angiography

- MR
  - Diffusion: infarction
  - Perfusion imaging: ischemia
    Arterial Spin Label Imaging / DCS perfusion
  - Flair T2: timing
  - Susceptibility Weighted Imaging: Heme
  - MRA, MR Venography
CT ANGIOGRAPHY

Easy and quick to perform

0.625 mm sections
mid heart to vertex

lipid laden plaque, ca++,
lumen stenosis, reformatted
images of neck and COW

CTA of Carotid Stenosis

71 M with amaurosis fugax

CT Findings in Acute Stroke

- Early
  - Perfusion deficit
  - Hyperdense MCA 34%
  - Hypodense tissue
    » “Insular ribbon”
    » Basal ganglia hypodensity
  - Mass effect
    » sulcal effacement

- Late Encephalomalacia

von Kummer et al.
Radiology 1997;205:327-333
66 yr old with acute hemiparesis, mild aphasia
Non contrast CT at admission

Minimal abnormality-- maybe low density in Left putamen... ??

CT Perfusion

Mean Transit time

3 parameters:
- Regional Cerebral Blood Volume (rCBV)
- Mean Transit Time (MTT)
- Regional Cerebral Blood Flow (rCBF = rCBV / MTT)

Collateral Flow Influences
Stroke location and volume

proximal M1 occlusion TIMI 0, with great collateral flow via ACA

CT based CBV/ hypodensity

“Penumbra” assessment
MTT – CBV = tissue at risk

May help determine futile cases

“Favorable” penumbra:
- Infarct core ≤ 70% of total perfusion deficit
- Infarct core < 90 ml (1/3 MCA)
Lateral view Angiogram, capillary phase, shows areas of poor collateral flow.

Kim et al

Follow-up CT at 7 days clearly demonstrates a left MCA infarct as predicted by the vascular defect on angiography.

Differential diagnosis: Migraine, post-ictal, Tumor, TIA

MR Diffusion detects small embolic infarctions
2mm thick slices

Baseline CT
32hr DWI
Goals of Stroke Imaging

- Is stroke or ischemia present?
  - Hemorrhage vs bland infarction/ischemia
  - Infarction vs other diseases

- Timing of stroke
  - Is it within a treatment window for tPA?
  - Flair-diffusion mismatch

- Treatment options

Flair – Diffusion Mismatch
“Tissue Clock”

- Evolution of FLAIR T2 Signal takes time compared with DWI

- Mismatch between DWI and FLAIR images
  - Identify patients likely to be within a time window of 4.5 hours
  - This may prove useful for timing of wake up strokes

- Flair – DWI mismatch does not allow exact timing of stroke onset

- Withholding of treatment based on Flair-DWI match is not appropriate (30% of strokes in tPA window have Flair signal)
**DWI-FLAIR Mismatch**

Song et al Stroke 2012

- Reader-measured signal intensity ratio of 1.15 can identify patients within the treatable time window of 4.5 hours (positive predictive value= 0.90)

**Acute infarct in left angular artery with evidence of reperfusion at 19-hour**

<table>
<thead>
<tr>
<th>DWI</th>
<th>FLAIR</th>
<th>rMTT</th>
<th>rCBV</th>
<th>MRA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19hrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reperfusion/ Luxury perfusion in left angular artery territory

---

**Use of FLAIR Imaging to Identify Onset Time of Cerebral Ischemia in a Canine Model**


<table>
<thead>
<tr>
<th>Flair</th>
<th>DWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 hr</td>
<td></td>
</tr>
<tr>
<td>4 hr</td>
<td></td>
</tr>
<tr>
<td>5 hr</td>
<td></td>
</tr>
<tr>
<td>6 hr</td>
<td></td>
</tr>
<tr>
<td>24 hr</td>
<td></td>
</tr>
</tbody>
</table>

---

**Flair Vascular Hyperintensity / DWI mismatch** Legrand, AJNR 2015

Initial MRI

Follow-up MRI

Post TPA

FVHs beyond the DWI lesion represent markedly impaired hemodynamics in patients with proximal occlusion and is a surrogate to large DWI-PWI mismatch.
**Arterial Spin Labeling**

- Blood is labeled in neck and imaged in the brain following a short delay.
- Labeled protons decay with the blood T1 time, which is on the order of 1 to 2 seconds.
- Flow that arrives late, i.e., through collateral pathways, may be incorrectly interpreted as absence of flow, but slow and increased flow is visible without contrast injection.

**High Resolution Spiral CASL**

- **TR:** 5 sec
- **FOV:** 24 cm
- **pts:** 4096
- **arms:** 4
- **thick:** 6 mm
- **skip:** 3 mm
- **label:** 2.5 s / 1 s
- **loc:** 2 cm
- **amp:** 0.038 G
- **pairs:** 8
- **scan time:** 5:30

**10 year old awoke w HA in AM followed at noon by acute right sided weakness, sensory changes. MRI 5pm: mild hemiplegia but word finding resolved. Hemiplegic migraine.**
55-year-old woman with a history of hemiplegic migraines presented with new onset right frontal headache, left-sided numbness, weakness, and dysarthria. The patient took prochlorperazine (Compazine) at home without relief of her symptoms.

CBF in Familial Migraine


- A biphasic CBF pattern was reported in 4 patients with prolonged aura in familial hemiplegic migraine type 2
- Initial hypoperfusion followed by hyperperfusion at around 18 hours
- CBF changes quickly within a day of the onset of symptoms.

ASL or SPECT over time following migraine


Chronic Headaches, initially thought SIH
But OP 40+. SSS meningioma found on ASL.
A 64-year-old man presenting with complex partial seizure

ASL shows increased signal in left transverse sinus

Susceptibility Weighted Imaging

- Increased conspicuity of blood products, calcification
- Gradient Echo (MPGR)
- 3D velocity encoded Gradient Echo

Susceptibility Weighted Imaging (SWI) detects disruption of magnetic field

- Reduced oxygen
- Within venous capillaries = Low signal on SWI

SWI detects:
- Calcification
- Hemorrhage
- Air Emboli
- DeoxyHgb
- Amyloid
42 year old male with interstitial lung disease
Thrombocytopenia on heparin

Kidwell et al NEJM 2013 “MR RESCUE”
- Randomized, standard care vs Embolectomy within 8 hours of AIS, 22 sites, 116 patients
- Favorable penumbral pattern = a predicted infarct core of < 90 ml and a proportion of predicted infarct tissue within the at-risk region of 70% or less
- Penumbra and Merci devices; recanalization rate 67% (< standard care w penumbra?)

“A favorable penumbral pattern on neuroimaging did not identify patients who would differentially benefit from endovascular therapy for acute ischemic stroke, nor was embolectomy shown to be superior to standard care”

Take Home Points
- Non Contrast CT: first line pre- IV TPA
- CTA: Large vs small vessel occlusion/ Carotid Vert
- MR diffusion most sensitive for acute stroke
- ASL: non invasive quantitative measure of CBF
  - Infarction, TIA, migraines, tumor, vascular malformations / AVF
- SWI- sensitive to blood / Ca++
- Flair – DWI mismatch may assist in timing of wake up strokes
- Perfusion / Diffusion mismatch:
  - Reflects status of collateral flow
  - CT and MR perfusion demonstrates tissue at risk, but embolectomy not better than standard medical therapy (Kidwell)
- CT and MR Perfusion: should not delay IV TPA