Imaging Modalities in Acute Stroke:

Time is Brain

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Stroke - Definition and Statistics

- Acute, vascular injury to CNS
  - <24 hrs = TIA
  - >24 hrs = stroke (CVA)
- Affects 600,000 people/yr
  (that is 1 stroke per minute!)
- Is #3 cause of mortality in adults
- Is #1 cause of disability

http://www.swmed.edu/stars/resources/stroke.html
Types of Stroke

- **Hemorrhagic (20%)**
  - usually hypertensive hemorrhage

- **Ischemic (80%)**
  - **Thrombotic (40%)**
    - intracerebral atherosclerosis
  - **Embolic (60%)**
    - Cardiac embolus (thrombus, tumor, septic embolus)
    - artery-to-artery (mainly carotid thrombus)
    - Paradoxical embolus (thrombus, fat, air)
Risk Factors for Stroke

- Atherosclerosis risk factors
  - Family history of CVA, TIA, or MI
  - Hypertension
  - Smoking
  - Diabetes
  - Hypercholesterolemia
- Previous CVA, TIA, or MI
- Atrial fibrillation
Our Patient - BF

- 86 yo F w/ Hx of HTN, CAD s/p MI, and high cholesterol
- presented to PCP for routine visit
- Felt “funny” -> began seizing
- In ED, unresponsive, L. sided hemiplegia
  eyes deviated to the right
Differential Diagnosis

- Many CNS diseases can mimic ischemic stroke
  - Hemorrhage
  - Mass lesion (tumor, abscess, AVM)
  - Seizure (Todd’s paralysis)
  - Hemiplegic migraine
  - MS flare
  - Venous infarct
Goals of Imaging in Acute Stroke

1. Rule in or out other disease processes
2. Define location, extent and age of infarct
3. Do so as rapidly as possible

TIME IS BRAIN
Cerebrovascular Anatomy

Posterior Circulation

Posterior cerebral artery
Superior cerebellar artery
Basilar artery
Anterior inferior cerebellar artery

Anterior Circulation

Posterior inferior cerebellar artery
Vertebral artery
Anatomy of the Anterior Circulation

Anterior cerebral artery

Middle cerebral artery

Internal carotid artery

Anterior cerebral artery

Middle cerebral artery

Internal carotid artery
Vascular territories in the brain
Imaging Modalities in Acute Stroke

- CT without contrast
- Conventional MRI
- Diffusion-Weighted and Perfusion MRI
- MRA
- Ultrasound
CT Imaging in Acute Stroke - 1

- **Initial test of choice**
- Best modality for detecting hemorrhage
- Identifies mass lesions (tumor, abscess, AVM)
- Fast and readily available

= Crucial for stroke triage (rule in/out other diseases)
CT Imaging in Acute Stroke - 2

**HOWEVER,**

- CT is poor at detecting acute infarcts
- Only 40% sensitivity <24 h

Film Findings for our patient, BF:
Normal Initial Head CT
2 hours post stroke
Our patient BF: CT#2 – 8 hours later

- As time passes, classic signs of stroke appear:
  - Loss of gray-white matter differentiation
  - Sulcal effacement

Patient #1 – BF; 8 hrs post stroke
Our patient BF CT#3 - 2 days later

Complete loss of gray-white matter differentiation

? hemorrhagic transformation

Sulcal effacement
Therefore, other imaging modalities are used to detect strokes < 6 hours!
Imaging Modalities in Acute Stroke

- CT without contrast
- **Conventional MRI**
  - Diffusion-Weighted and Perfusion MRI
  - MRA
- Ultrasound
Conventional MR Imaging in Stroke

- Slight incr. detection rate over CT in early stroke
- T2 hyperintensity visible at 12-24 hrs (80% +)
  - represents edema
- May see absent flow voids = arterial occlusion

**T1 imaging basics**
- CSF is dark
- Soft tissue is bright
- Good for mass lesions

**T2 imaging basics**
- CSF is bright
- Soft tissue is dark
- Good for edema (bright)
Conventional MR Imaging in Stroke

- Our patient, BF, underwent an MRI study immediately following her initial CT, 2 hours after her stroke.

Film Findings:

Normal Initial MRI:
- ? Absent R. MCA Flow Void (suggestive of MCA occlusion)
Our patient BF - MRI #2: 30 hours later

- At 30 hrs., classic MR signs of infarct are present

Film Findings:
T2 hyperintensity in temporal lobe, MCA distribution
Conclusions - Conventional MR Imaging in Acute Stroke

- Conventional MRI can detect acute infarcts slightly earlier than CT

- Nonetheless, additional techniques are still needed for early stroke detection
Imaging Modalities in Acute Stroke

- CT without contrast
- Conventional MRI
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Osmotic pump failure is 1st event in ischemia
Fluid shift extracellular->intracellular
Water in cells now can’t diffuse!

Detected as decreased diffusion coefficient (ADC)
Increased restriction of diffusion (DWI)

Detects change within 30 minutes of onset of stroke
Beats T2 signal by 3-6 hours !!!

Our Patient had a DWI MRI immediately following the initial routine MRI
In our patient, DWI sequences were performed during her initial MRI.

A faint increase in DWI signal was observed in the temporal and insular cortex.

Indicated early ischemia in MCA territory.

Led to treatment with IV thrombolytic therapy (t-PA).
That’s good, but could we predict how bad her stroke might get?
Imaging the Penumbra: the Holy Grail of Stroke Diagnostics

- DWI is thought to show the area currently infarcting.
- But is there an “area at risk” where blood flow is reduced but cells haven’t died yet?
- Imaging this region (the penumbra) = goal of MR perfusion imaging

- Uses gadolinium for contrast
- Changes magnetic properties of perfused tissue vs. non-perfused
- Measures decreased flow in penumbra!
  - increased mean-transit-time (MTT) of blood flow to penumbra
Correlation of Perfusion Imaging with Infarct Progression


↑MTT
- area of low/slow blood flow
- area at risk for stroke extension

Early (2h):
- small area of injury

Late (29h):
- larger area of injury (correlates with 2h MTT)

DWI
Progression of Infarct in BF: DWI at 30 hrs post-stroke

normal DWI
normal brain

serial, axial sections demonstrating extent of infarct at 30 hours
normal DWI
normal brain

BIDMC

30
increased DWI
injured brain
increased DWI
injured brain
increased DWI
injured brain
increased DWI
injured brain
increased DWI
injured brain
DWI in 3D - 9

increased DWI
injured brain
increased DWI
injured brain
increased DWI
injured brain
Increased DWI in injured brain.
increased DWI
injured brain
Summary – Extent of infarct

our patient

R. MCA territory

R. PCA territory (complete)

BIDMC

MGH Handbook of Neurology
Imaging Modalities in Acute Stroke

- CT without contrast
- Conventional MRI
- Diffusion-Weighted and Perfusion MRI
- MRA
- Ultrasound
MRA/Angiography of occluded MCA

Patient BF; R. MCA occlusion

our patient – R. MCA

BIDMC

Patient BF; R. MCA occlusion

companion patient – L. MCA

BIDMC

L. MCA occlusion - literature

Bahn et al. JMRI 6:833-845, 1996
Imaging Modalities in Acute Stroke

- CT without contrast
- Conventional MRI
- Diffusion-Weighted and Perfusion MRI
- MRA
- Ultrasound
Ultrasound in Stroke

- Has a primary role in working up cause of stroke
- Echocardiography
  - TEE for LA/LV thrombus
  - Bubble echo study for PFO (paradoxical embolus)
- Carotid Ultrasound
  - Evaluates patency of carotids and degree of stenosis
- Transcranial Doppler Ultrasound
  - Evaluates patency of intracranial arteries (MCA)
Summary I – Patient Course

- BF was given t-PA within 3 hours of onset
  - 30% increase in recovery over controls
    (31% t-PA vs. 20% placebo = minimal/ no disability @ 3 mos.)
  - 6-fold increased risk of bleeding (6% vs. 1%?)
- Symptoms of stroke did not improve considerably
- Intubated in ICU for 1 week
- Transferred to floor with residual weakness
- Discharged to rehabilitation facility after 10 days
<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>Time of post-stroke imaging</th>
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<tbody>
<tr>
<td></td>
<td>2h</td>
</tr>
<tr>
<td>CT without contrast</td>
<td>-</td>
</tr>
<tr>
<td>Conventional MRI</td>
<td>-</td>
</tr>
<tr>
<td>DWI MRI</td>
<td>+</td>
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<tr>
<td>MRA</td>
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+ = evidence of acute stroke; - = no evidence of acute stroke; ND = not determined
Summary III – Imaging in Stroke

Acute Stroke (<6 hours)

- **CT (without contrast!!)**
  - Excellent for ruling out hemorrhage, other diseases
  - Poor in defining early infarcts

- Conventional MRI (T1,T2)
  - Bad for hemorrhage, fair for early infarcts

- Diffusion-Weighted and Perfusion MRI
  - Excellent for defining early infarcts (1-2 hrs)
    and for estimating areas at risk
Summary IV - Imaging in Stroke

Sub-acute Stroke (>6 hours)

- CT (without contrast)
  - Excellent in defining late infarcts (>24 h)
    - sulcal effacement, loss of gray-white differentiation

- Conventional MRI (T1, T2)
  - Better than CT at 6-24h; Same as CT in infarcts > 24h
    - T2 hyperintensity is most indicative of injury

- Ultrasound
  - Critical for workup of origin of stroke (TEE, TCD, Carotid Doppler)
Summary V - Imaging in Stroke

- In the near future, there will hopefully be effective treatments for acute stroke.
- Patients will need to come to the ER at first sign of “brain attack”.
- Patients will need to be imaged by multiple modalities rapidly.
- Remember ...

TIME IS BRAIN
References

AHA Website: http://www.americanheart.org/statistics/stroke.html
UT Southwestern STARS Website: http://www.swmed.edu/stars/resources/stroke.html
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