What A Picture: Imaging in Acute Stroke

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Outline

• Cases
• Vascular Anatomy
• Clinical presentations of stroke
• Rapid imaging
• Guidance of treatment
Case

• 58 year old male with AF on rivaroxaban, DM, and RA presenting with right-sided weakness, aphasia, left gaze/head turn preference

• NIHSS 12
• Last seen well (LSW) 12 hours prior to arrival

• No tPA given anticoagulation, LSW

• What type of imaging should be obtained?
Case

- OSH CTH: ASPECT 9 (insula)
- Transferred for possible intervention given cortical signs
- MRA: Left M1 thrombus
Case

- MRI: Small left insular and thalamocapsular stroke
- Clinical/Imaging mismatch
- Taken emergently for thrombectomy, with resultant successful reperfusion (TICI2b)

- NIHSS 12 → 4
Information from Imaging

- Identify suspected stroke etiology (ischemic vs. hemorrhagic)
- Evaluate brain tissue viability & perfusion
- Define vessel status (occlusion vs. patent)
- Guide therapeutic decisions
Localization – Vascular Anatomy
Anatomy

Extra-Cranial Vasculature

• Carotid arteries (anterior)
• Vertebral arteries (posterior)
Anatomy

Intra-Cranial Vasculature

• Carotid arteries (anterior)
• Vertebral arteries (posterior)
Anatomy

A
- Anterior communicating artery
- Anterior cerebral artery
- Middle cerebral artery
- Internal carotid artery
- Posterior communicating artery
- Posterior cerebral artery
- Superior cerebellar artery
- Basilar artery
- Anterior inferior cerebellar artery
- Posterior inferior cerebellar artery
- Anterior spinal artery

B
- Int. carotid
- Ant. communicating
- Ant. cerebral
- Arterial circle
- A.M.
- P.M.
- Post communicating
- Pontine
- Internal auditory
- Posterior inferior cerebellar
Stroke Syndromes
Stroke Syndromes - MCA

Supplied by anterior cerebral artery

Infarct of left middle cerebral artery

Supplied by posterior cerebral artery
Stroke Syndromes - MCA

- Aphasia – Dominant
- Hemi-spatial neglect - Non-dominant
- Ipsilateral gaze preference – Frontal eye fields
- Contralateral Face/Arm > Leg paralysis +/- sensory loss – Pre & Post-central gyrus
- Contralateral hemianopia – Optic radiations
Stroke Syndromes - ACA
Stroke Syndromes - ACA

• Contralateral Leg >> Face/Arm paralysis +/- sensory loss – Pre- & Post-Central gyrus

• Abulia/apathy – Anterior cingulate gyrus/caudate head
Stroke Syndromes

• 85 year old female with history of CAD, HTN, HLD and DM presenting after found down (LSW ~18 hours prior)

• NIHSS 25 with L sided weakness, R gaze preference
Stroke Syndromes - ICA

- CTA: R ICA occlusion extending intracranially, with poor collaterals
Stroke Syndromes

ICA

- MCA + ACA deficits (T-occlusion)
- Amaurosis fugax (CRAO)
Stroke Syndromes - Basilar

- Brainstem localization
- Lateral gaze palsy – CN VI
- Hemiparesis – Desc. Corticospinal tracts
- Dysarthria – CN X, XII
Stroke Syndromes

Midbrain – PCA + basilar/perforators
- “Top of the Basilar”
  - Bilateral midbrain & thalamic structures
- Artery of Percheron

- CN III palsy – Oculomotor nucleus
- Contralateral hemiparesis -- Corticospinal tract/Cerebral peduncles
- Internuclear ophthalmoplegia – Medial Longitudinal Fasiculus
- Ipsilateral ataxia – Superior cerebellar peduncles
- Ipsilateral tremor – Red nuclei
Stroke Syndromes – Artery of Percheron

• Patient presenting with acute onset coma

• Azygous variant branch of the posterior cerebral artery, supplying bilateral thalamus
Stroke Syndromes

Pons – Basilar
• ‘Locked In’
  • Bilateral ventral pons infarct

• Contralateral hemiparesis – Corticospinal tract/Basis pontis
• Hemianesthesia – Ascending sensory tracts
• Ataxic hemiparesis – Crossing cortico-pontocerebellar tracts
• Horizontal gaze palsy – CN VI nucleus, paramedian pontine reticular formation (‘lateral gaze center’)

[Diagram of the pons with labeled blood vessels and nerves]
Stroke Syndromes

Medulla – PICA, ASA

• Wallenberg/Lateral Medullary Syndrome
  • Dysphagia & dysphonia – Nucleus Ambiguus, CN X, CN IX
  • Vertigo – CN VIII, vestibular nuclei
  • Ipsilateral Horner’s – Desc. Sympathetic tracts
  • Ipsilateral Face + contralateral body sensory loss – Trigeminal & spinothalamic tracts
  • Ipsilateral ataxia – Spinocerebellar tract

• Medial Medullary Syndrome
  • Ipsilateral tongue weakness – CN XII
  • Contralateral hemiparesis – Pyramidal tracts (rostral to decussation)
Stroke Syndromes - PCA
Stroke Syndromes - PCA

- Contralateral homonymous hemianopia – Occipital lobe
- “Alexia without Agraphia”
  - Splenium + left PCA
Stroke Syndromes - Cerebellar

• PICA – Lateral medulla + cerebellar hemisphere
  • Ipsilateral limb dysmetria, dyssynergia, intention tremor, dysdiadochokinesia

• AICA – Pontine structures + cerebellum
  • Vertigo + ipsilateral hearing loss – Vestibulocochlear nerve and inner ear
  • Ipsilateral upper and lower facial weakness – CN VII

• SCA – Midbrain + small area of rostral cerebellar hemisphere
  • Ipsilateral cerebellar signs
Stroke Syndromes

Lacunar
- Pure motor
- Pure sensory
- Sensorimotor
- Ataxic hemiparesis
- Dysarthria-clumsy hand
Cerebral Blood Flow

The diagram illustrates the relationship between Cerebral Perfusion Pressure (mm Hg) and Cerebral Blood Flow. It highlights the zone of normal autoregulation, where the blood flow remains constant despite changes in perfusion pressure. Below this zone lies the range of hypoperfusion, and above it, the effects of disrupted autoregulation. The figure also indicates maximum dilation and constriction at different pressure levels.
Time to symptoms...

• Ischemic core: irreversible cell injury
• Ischemic penumbra: tissue at risk
• Collateral blood flow → sustains the penumbra
Collaterals

Extent of infarction depends on presence of collateral circulation

Common Routes:

• **Bilateral vertebral artery occlusion**—anterior spinal artery

• **Common carotid artery occlusion**—contralateral common carotid artery via ipsilateral external carotid artery or vertebral artery via ipsilateral occipital artery

• **Internal carotid artery occlusion**—ipsilateral external carotid artery via ophthalmic artery or circle of Willis

• **Middle cerebral artery occlusion**—ipsilateral anterior or posterior cerebral artery via leptomeningeal anastomoses
Information from Imaging

- Identify suspected stroke etiology (ischemic vs. hemorrhagic)
- Evaluate brain tissue viability & perfusion
- Define vessel status (occlusion vs. patent)
- Guide therapeutic decisions
Imaging – CT vs. MRI

- CTH
- CTA
- CT Perfusion
- MRI
  - DWI
  - ADC
  - GRE/SWI
  - FLAIR
- MRA
- MR Perfusion
Imaging

• 73 year old male presenting with acute onset of left sided weakness (face, arm, leg), dysarthria
• NIHSS 8
• LSW 3 hours prior to presentation

• Localization?
  • Descending right corticospinal tract

• Mechanism?
  • Lipohyalinosis (small vessel) vs. other
Stroke Type

- Intracranial Hemorrhage
- CTH: right basal ganglia hemorrhage
Stroke Type

- Intracranial hemorrhage

- MRI GRE: large left frontal hemorrhage with edema, mass effect
Stroke Type
MRI - Intracranial Hemorrhage

• GRE/SWI
Vascular Signs in CT & MRI

A) Hyperdense MCA

B) MCA blooming artifact
CTA vs. MRA for vessel occlusion

**CTA**
- CTA – sensitivity 92-100%

**MRA**
- MRA – 80-90%
Vessel Status

Sub-occlusive thrombus in left internal carotid artery
CTH vs. MRI DWI for early ischemic changes

**CTH**
- CTH – sensitivity 20-75%

**MRI**
- MRI – sensitivity 91-100%
ASPECT Score

Alberta Stroke Program Early CT Score

- CTH axial cuts

- Ganglionic level (M1-M3, insula, lentiform nucleus, caudate nucleus, posterior limb of internal capsule)

- Supra-ganglionic level (M4-6)
ASPECT – 10

60 year old male presenting with right-sided weakness and language difficulty; NIHSS 9
ASPECT - 8

71 year old male presenting with left sided weakness, numbness and dysarthria; NIHSS 5

Hypodensity in caudate and loss of gray/white differentiation in insular ribbon
ASPECT - 2

- 52 year old male, found down with left sided weakness; NIHSS 23

Hypodensity in lentiform nucleus, insula, M1-3, M4-6
ASPECT - 7

- 55 year old male with aphasia and visual field cut.

Internal capsule, M3, M6
Case

- 71 year old female with AF not on AC, HTN, presenting with L sided weakness, dysarthria and neglect (NIHSS 6) with LSW 2 hours prior
- ASPECT 9 (R insula)
- Given tPA after telestroke → transferred for possible thrombectomy
Case

• MRI brain: right insular stroke
• MRA head: right M2 occlusion

• Post-tPA, NIHSS 6 -> 0
• No further intervention; discharged on AC
Reperfusion Candidates: Left MCA Occlusion

A) Left MCA occlusion + poor collateral flow
B) Hypodensity + hemorrhagic conversion

C) Left MCA occlusion + strong collateral flow
D) Complete recanalization
Early Ischemic Changes

- DWI = measure of net movement of water in tissue due to molecular motion
- ADC = reduction in intracellular space associated with disruption of membrane ionic homeostasis and cytotoxic edema
- DWI/ADC/FLAIR
Case

• 62 year old female with history of HTN, presented after car accident when she was found with aphasia and confusion.
• NIHSS 8 (LOCq 2, FP 2, RUE 1, RLE 1, lang 1, dys 1).
• LSW within 2 hours
MRI – DWI/ADC/FLAIR in acute stroke
Case

• 68 year old male with history of HTN, found down with unintelligible speech and right visual field cut

• LSW 6 days prior to presentation ...
MRI – DWI/ADC/FLAIR in subacute stroke
MRI

- DWI hyperintense (bright) + ADC hypointense (dark) = irreversible ischemia/infarction

- DWI hyperintense + ADC hypointense + FLAIR hyperintense = subacute/chronic infarction
  - T2 shine-through – occurs > 4.5 to 6 hours after ischemia
Stroke Timing on Imaging – Temporal changes in MRI
### Timing of Intracerebral Hemorrhage

<table>
<thead>
<tr>
<th>Stage</th>
<th>Phase of Blood</th>
<th>Noncontrast CT</th>
<th>T1-Weighted MRI</th>
<th>T2-Weighted MRI</th>
<th>T2*-Weighted MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperacute</td>
<td>Oxyhemoglobin</td>
<td>Smooth, hyperdense</td>
<td>Hypointense or isointense</td>
<td>Hyperintense</td>
<td>Marked hypointensity</td>
</tr>
<tr>
<td>Acute (12–48 hours)</td>
<td>Deoxyhemoglobin</td>
<td>Hyperdense with fluid levels</td>
<td>Isointensity or slight hypointensity with thin hyperintense rim in the periphery</td>
<td>Hypointense with hyperintense perilesional rim</td>
<td>Marked hypointensity</td>
</tr>
<tr>
<td>Early subacute (72 hours)</td>
<td>Methemoglobin intracellular</td>
<td>Hypodense region of edema with mass effect</td>
<td>Hyperintensity</td>
<td>Hypointensity</td>
<td>Hypointensity</td>
</tr>
<tr>
<td>Late subacute (3–20 days)</td>
<td>Methemoglobin extracellular</td>
<td>Less intense with ringlike profile</td>
<td>Hyperintensity</td>
<td>Hyperintensity</td>
<td>Hypointensity</td>
</tr>
<tr>
<td>Chronic (9 weeks)</td>
<td>Hemosiderin and ferritin</td>
<td>Isodense or modest confined hypodensity</td>
<td>Hypointensity</td>
<td>Hypointensity</td>
<td>Hyperintense or isointense core surrounded by hypointense rim</td>
</tr>
</tbody>
</table>
Stroke Mechanisms on Imaging (MRI DWI)
Stroke Mechanism

- Patient presenting with vertigo, nausea and committing.
- A) CTH normal
- B) CTA irregularity in R vertebral
- C) MRI infarcts in PICA distribution
- D) MRA confirms vertebral dissection
Intracerebral Hemorrhage Mechanism - HTN
Diffusion-Perfusion Mismatch

• Estimates volume of penumbral regions which may be saved vs. core that cannot be saved & increase risk of hemorrhagic transformation

• CT perfusion
• MR perfusion
**Imaging – Perfusion**

**TABLE 2-1 Hemodynamic (Computed Tomography/Magnetic Resonance Perfusion) Parameters in Cerebral Ischemic Infarct**

<table>
<thead>
<tr>
<th></th>
<th>Time Parameters (MTT, TTP, Tmax)</th>
<th>Cerebral Blood Volume</th>
<th>Cerebral Blood Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemic penumbra</td>
<td>Mildly increased</td>
<td>Mildly increased or normal</td>
<td>Mildly decreased</td>
</tr>
<tr>
<td>Infarct core</td>
<td>Markedly increased</td>
<td>Mildly decreased</td>
<td>Markedly decreased</td>
</tr>
</tbody>
</table>

MTT = mean transit time; Tmax = time to maximum; TTP = time to peak.

*a* Cerebral blood volume (CBV) is the total volume of blood in a given unit of brain volume (mL/100 g). Cerebral blood flow (CBF) is the volume of blood moving through a given unit of brain volume per unit time (mL/100 g/min). Mean transit time (MTT) is the average transit time of blood through a given brain region in seconds. The central volume principal is defined as CBF = CBV/MTT.
Mismatch Profiles

Top: Target profile

Bottom: Malignant profiles
CT Perfusion – Left MCA Occlusion
Case

- 69 year old male with CAD, HTN, HLD, +smoking, and R ICA stent presenting with left-sided weakness, right gaze, dysarthria, NIHSS 14; LSW 4.5 hours

- CTH ASPECT 9

- CTA head/neck: Occlusion vs. trickle flow in R ICA stent + R M1 thrombus
Case
Case

- Transferred by air and taken emergently to angio for thrombectomy
- S/p R ICA stent + thrombectomy
- NIHSS -> 8
Final Notes
<table>
<thead>
<tr>
<th>Neuroimaging Modality</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parenchyma</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncontrast CT</td>
<td>Fast acquisition time, widely available, sensitive to hemorrhage</td>
<td>Limited sensitivity to infarct size, location of early ischemia</td>
</tr>
<tr>
<td>Diffusion-weighted MRI</td>
<td>Sensitive to early ischemia, fast acquisition time, high conspicuity of lesion</td>
<td>Lack of availability, patient contraindications (e.g., metals, claustrophobia), long acquisition time</td>
</tr>
<tr>
<td><strong>Vasculature</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT angiography</td>
<td>Quantify vascular disease burden (e.g., degree with stenosis, length of clot, characteristics of plaques), fast acquisition time</td>
<td>Potential renal toxicity, allergy to contrast agents; radiation exposure; provides no information on direction or velocity of flow</td>
</tr>
<tr>
<td>Magnetic resonance angiography</td>
<td>No contrast</td>
<td>Overestimates stenosis, sensitive to motion and other technical artifacts, long acquisition time, patient contraindications (e.g., metals, claustrophobia)</td>
</tr>
<tr>
<td>Ultrasound (carotid or transcranial Doppler)</td>
<td>Flow data, portable, low cost</td>
<td>User dependent, time consuming, technical constraints</td>
</tr>
<tr>
<td><strong>Tissue Perfusion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT perfusion</td>
<td>Fast acquisition time</td>
<td>Potential renal toxicity, allergy to contrast agents; radiation exposure; qualitative</td>
</tr>
<tr>
<td>Magnetic resonance perfusion</td>
<td>Good spatial resolution</td>
<td>Qualitative; patient contraindications (e.g., metals, claustrophobia), requires gadolinium</td>
</tr>
<tr>
<td>Positron emission tomography (PET)</td>
<td>Gold standard for cerebral blood flow measures, provides quantitative measures of physiologic parameters (oxygen extraction fraction and metabolism)</td>
<td>Requires multiple radiotracers with very short half-lives, thus impractical in acute settings; low resolution, limited availability</td>
</tr>
</tbody>
</table>

*CT* = computed tomography; *MRI* = magnetic resonance imaging.
Vascular Imaging Strategies

• 1) CTH + CTA +/- CTP
• 2) CTH + DSA
• 3) MRI +/- MRA
Treatment of Acute Ischemic Stroke

• No minimum NIHSS precludes tPA if symptoms are disabling
• NIHSS > 5 + large vessel occlusion $\rightarrow$ endovascular therapy

• NIHSS biases
  • Higher scores for dominant hemisphere strokes (aphasia)
  • Underestimation in posterior circulation strokes
IV Tissue Plasminogen Activator

Indications: Diagnosis of ischemic stroke, symptom onset within 4.5 hours, age > 18 years

Contraindications:

• Severe head trauma, ischemic stroke within 3 months
• Arterial puncture at non-compressible site (7 days), recent intracranial or spinal surgery (3 months), intracranial neoplasm or aneurysm, active bleeding
• Systolic blood pressure > 185 or diastolic > 110
• INR > 1.7, platelets < 100, heparin within 48H with abnormal PTT
• Glucose < 50
• CT with hypodensity > 1/3 cerebral hemisphere
Intraarterial thrombectomy

• Recommended inclusion:
• > 18 years
• Baseline mRS 0-1
• NIHSS ≥ 6
• Internal carotid artery inclusion or M1 occlusion
• ASPECT score > 6
• LSW < 6 hours
Information from Imaging...

• Ischemic or hemorrhagic?
• Size and location?
• Cause of stroke?
• Candidate for tPA?
• Large vessel occlusion present?
• Candidate for thrombectomy?
• Presence of penumbra?
References


