Disclosures

- No conflicts of interest to disclose
Neuroimaging 101

- Plain films
- Computed tomography
  - Angiography
  - Perfusion
- Magnetic resonance imaging
  - Diffusion-weighted Imaging
  - Spectroscopy
  - Functional MRI
  - Diffusion Tensor Imaging
- Angiography
- Myelography
- Ultrasound
- Nuclear Medicine
  - Positron Emission Tomography
  - Single-photon Emission Computed Tomography
  - Cerebral Blood Flow
Neuroimaging 101

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Neuroimaging 101

- Magnetic resonance imaging
  - Diffusion-weighted Imaging (DWI)
  - Spectroscopy (MRS)
- Nuclear Medicine
  - Single-photon Emission Computed Tomography (SPECT)
  - Cerebral Blood Flow (CBF)
MRI: Overview
Introduction

- Patterns of abnormal imaging findings:
  - Diffuse
  - Focal
  - Multifocal
- Neurotoxic disease
  - Usually diffuse
  - Occasionally multifocal
  - Commonly sub-MRI
Standard MRI

- T1
- T2
- FLAIR
- DWI
- ADC
- GRE

Contrast needs to be specified
MRI sequences

- T1 with and without contrast
- T2
- FLAIR
- Diffusion-Weighted Imaging (DWI)
- Apparent Diffusion Coefficient (ADC)
- Gradient Echo (GRE)

- All are done in axial plane, some also done in sagittal and coronal
How does a CT scan help?

- Screening test
  - Hemorrhage
  - Focal lesion
  - Severe diffuse disease
- Trauma/fractures
- Calcified lesions
- Temporal bone/sinus disease
CT versus MR

- CT - differential attenuation of x-ray
- MR - response of tissue to magnetic field
FLAIR imaging

- Fluid attenuated inversion recovery
- T2-based image
- Attenuates the bright signal of CSF on the usual T2 image
- White matter = gray
- Gray matter = white
Comparison (non-contrast)
Comparison (non-contrast)

T2  FLAIR
Vasogenic and Cytotoxic Edema

**Vasogenic**
- Reactive process
- Bilateral if toxic
- Unilateral if surrounding a mass lesion
- Predominantly white matter
- Improves with steroids

**Cytotoxic**
- Primary process, tissue injury
- Unilateral or bilateral
- Affects gray and white matter
- Does not respond to corticosteroids
MRI: Diffusion-Weighted Imaging (DWI)
DWI

- Diffusion of water is rapid in normal brain parenchyma and in vasogenic edema (normal signal)
- Diffusion is restricted in cytotoxic edema (bright signal)
- Apparent diffusion coefficient (ADC) is used to verify diffusion restriction versus artifact
DWI/ADC

- Non-invasive, physiologic imaging
- Highly sensitive to tissue injury
  - More sensitive than T1/T2/FLAIR
  - Can show cerebral ischemia within minutes
- ADC correlation
  - Acute vs. chronic infarct
  - Infarct vs. artifact
  - Cytotoxic vs. vasogenic edema
DWI/ADC
Cytotoxic Edema on MRI

DWI

ADC
Acute Ischemic Stroke
Acute Ischemic Stroke
Acute Ischemic Stroke
Acute Ischemic Stroke
Acute Ischemic Stroke

FLAIR  DWI  ADC
Cerebral Metastatic Disease

FLAIR  DWI  ADC
Cerebral Metastases

GRE

T1 +C
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion

FLAIR

DWI

ADC
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion

FLAIR  DWI  ADC
Hydrogen Peroxide Ingestion
Hydrogen Peroxide Ingestion

FLAIR

DWI

ADC
Posterior Reversible Encephalopathy Syndrome
Posterior Reversible Encephalopathy Syndrome
Posterior Reversible Encephalopathy Syndrome
Posterior Reversible Encephalopathy Syndrome
Posterior Reversible Encephalopathy Syndrome

FLAIR

DWI

ADC
Posterior Reversible Encephalopathy Syndrome

FLAIR

DWI

ADC
Posterior Reversible Encephalopathy Syndrome

FLAIR  DWI  ADC
Posterior Reversible Encephalopathy Syndrome

FLAIR

DWI

ADC
PRES – 4 Months Later

Initial FLAIR

Follow-up FLAIR
PRES – 4 Months Later

FLAIR    DWI    ADC
Delayed Post-Hypoxic Leukoencephalopathy - Heroin
Delayed Post-Hypoxic Leukoencephalopathy - CO

FLAIR

DWI

ADC
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury
Hypoxic-Ischemic Injury

FLAIR

DWI

ADC
Hypoxic-Ischemic Injury

FLAIR

DWI

ADC
Hypoxic-ischemic Injury

FLAIR

DWI

ADC
Hypoxic-Ischemic Injury

FLAIR

DWI

ADC
MRI Summary

- FLAIR- white matter edema, demyelination, inflammation, infarction
- DWI/ADC- cytotoxic vs. vasogenic edema
- T1- metal deposition (copper, manganese)
- GRE- hemosiderin
- Gadolinium contrast- BBB breakdown
MR Spectroscopy
MRS

- **Phosphorus**
  - Inorganic phosphorus, ATP
  - Measures energetic state, pH
  - Healthy tissue (Krebs cycle) vs. Ischemic tissue (glycolysis)

- **Proton**
  - Three usual peaks:
    - Creatine (Cr)
    - Choline (Cho)
    - N-acetyl aspartate (NAA)

- Lactate
MRS

- **Creatine**
  - Relatively constant

- **Choline**
  - Elevated with increased cellular turnover (e.g. neoplasm)

- **NAA**
  - Decreased in neuronal injury (e.g. infarction)

- **Lactate**
  - Increased in inflammation, infarction
<table>
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<th>Myo-inositol</th>
<th>Choline</th>
<th>NAA</th>
<th>Lactate</th>
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<td>++</td>
<td>+++</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Necrotic/treated tumor</td>
<td>-</td>
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<tr>
<td>HIE</td>
<td></td>
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<tr>
<td>Acute Demyelination</td>
<td>++</td>
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Classic findings

- Demyelination
  - Decreased NAA, Elevated Cho
- Alzheimer Disease
  - Elevated Myo-inositol
- Meningiomas
  - Elevated Alanine
- Canavan Disease
  - Markedly elevated NAA
Classic findings

- Doublet lactate peak
  - Stroke
  - Seizure (recent)
  - High-grade or necrotic neoplasms
- Hypoxic-ischemic encephalopathy
  - Elevated lactate, Decreased NAA
Clinical Uses of MRS

- Neoplasm or not
- Recurrent neoplasm vs. radiation necrosis
- Etiology of leukoencephalopathy
- Evaluating for metabolic disease
Images of MRS from literature withheld

See the following references:

SPECT and Cerebral Blood Flow Study

Nuclear Medicine
Nuclear Medicine

- Infuse radioactive compounds, then detect emissions with gamma cameras
- Technetium
  - Cerebral Blood Flow Study
- Indium (CSF)
  - Hydrocephalus study
  - Sinonasal CSF leak study
- Positron-emitting isotopes
  - Deoxyglucose PET
  - Dopamine PET
- SPECT
Cerebral Blood Flow
Cerebral Blood Flow

- Technetium 99m-HMPAO
- Planar imaging
- Imaging delayed after infusion
- In brain death, no tracer accumulates = “cold study”
CBF
CBF

- See the following reference for additional images:
SPECT

- Single photon-emission computed tomography
- Iodinated radiotracer or technetium agents
- Less expensive than PET
  - Agents are more stable
  - No cyclotron required
- Stroke, Epilepsy, Dementia, Parkinsonism
SPECT in Parkinsonism

- Radiotracer can be labeled for pre- or post-synaptic sites
- Presynaptic
  - DAT
  - VMAT
  - AADC
- Postsynaptic
  - D1 or D2 receptor
SPECT in Parkinsonism

- See the following reference for images:
  - Huang CC. “Parkinsonism induced by chronic manganese intoxication – an experience in Taiwan.” Chang Gung Med J 2007; 30: 385-95
Summary

- MR Spectroscopy – White matter lesion of unknown etiology
- SPECT – Differentiation of toxin-induced vs. idiopathic parkinsonism
- Cerebral blood flow studies – Confirmatory testing for brain death determination in poisoned patient