Neuroimaging of the Visual Pathways: From the Chiasm & Beyond

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Disclosures

• Carl Zeiss Meditec (speakers bureau)
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Anatomy slides courtesy of Lorraine Lombardi, PhD
Key Points

- Imaging techniques and scan selection
- Correlative neuro-anatomy and neuroradiology for visual pathway lesions
  - Chiasm
  - Retro-chiasm

Neuroimaging Studies

- Computed tomography (CT)
- Magnetic resonance imaging (MRI)

Ordering a Scan

- Scan selection (e.g. MRI, CT) and testing protocol:
  - Brain
  - Orbits
  - Pituitary/chiasm
- Without contrast
- Clinical impression/question to be answered
- Medical history
COMPUTED TOMOGRAPHIC (CT) SCANNING

Background
- Increased absorption of x-rays by atoms of higher atomic # (Ca, I, Fe)
- Axial & coronal image planes
- Iodinated IV contrast
  - contraindicated for px’s with hx of allergic rxn to previous contrast studies or shellfish, pregnancy or renal disease

CT “Windows”
- Brain / Soft Tissue
  - 50-350 HU (narrow window)
- Bone
  - 400-2000 HU (wide window)
7 y/o WM

- Hit in left eye with baseball bat
- + ecchymosis & sub conj hem
- No subjective diplopia or motility restriction
- Exoph = 17mm OU
27 y/o Man

- c/o vertical diplopia following blunt trauma
- Diplopia:
  - Near > Dist.
  - Alleviated on left head tilt
Pros & Cons of CT

- Cheap
- Quick
- Adaptable for angiography (CTA)
- Acute Blood
- Bone detail & orbits
- Soft tissue differentiation
- "Beam-hardening" artifacts
- Restricted imaging planes (axial & coronal)
- Ionizing radiation

Magnetic Resonance Imaging (MRI)
Background
- P in strong magnetic field
- Alignment vector for hydrogen atoms (protons)
- Radiofrequency (RF) pulse
- Energy absorbed / released
- Released signal (“echo”) analyzed by receiver coils
- Computed image construction

MRI Sequencing
- T1-weighted
- T2-weighted
- Fluid attenuated inversion recovery (FLAIR)
- Fat suppression
- Diffusion-weighted imaging (DWI)

T1-Weighted Imaging
- Short TR (< 600 ms)
- Short TE (< 30 ms)
- Good resolution of anatomical detail
- Adaptable with contrast infusion
T2-Weighted Imaging

- Long TR (> = 2000 ms)
- Long TE (> = 80 ms)
- Good identification of pathology (fluid)
  - Edema
  - Demyelination
  - Infarction

Signal Intensity (T-1 vs. T-2)

<table>
<thead>
<tr>
<th>Structure</th>
<th>T-1 weighted</th>
<th>T-2 weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain (white/gray)</td>
<td>bright</td>
<td>darker</td>
</tr>
<tr>
<td>CSF/H2O</td>
<td>dark</td>
<td>bright</td>
</tr>
<tr>
<td>Vitreous segment</td>
<td>dark</td>
<td>bright</td>
</tr>
<tr>
<td>Fat</td>
<td>very bright</td>
<td>less bright</td>
</tr>
<tr>
<td>Rapid blood flow</td>
<td>black</td>
<td>black</td>
</tr>
<tr>
<td>Bone/air</td>
<td>black</td>
<td>black</td>
</tr>
</tbody>
</table>
30 y/o AA Woman

- Clinical concern for papilledema
- BVA:
  - 20/20 OD
  - 20/20 OS
Signal Intensity (T-1 vs. T-2)
Abnormal Tissue

<table>
<thead>
<tr>
<th>Lesion</th>
<th>T-1 weighted</th>
<th>T-2 weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>Dark</td>
<td>Bright</td>
</tr>
<tr>
<td>Blood</td>
<td>Bright (early &amp; late subacute) Dark (hyperacute &amp; chronic)</td>
<td>Bright (hyperacute &amp; late subacute) Dark (acute / early subacute &amp; chronic)</td>
</tr>
<tr>
<td>Demyelinating plaques</td>
<td>Normal (acute) Dark (chronic) Black hole</td>
<td>Bright</td>
</tr>
<tr>
<td>Protein</td>
<td>Dark (low-%) Bright (mod-%) High</td>
<td>Bright (low-%) Dark (mod.-very high)</td>
</tr>
</tbody>
</table>
37 y/o man

- Hx of recent auto accident with whiplash injury
- Transient monocular blindness, OD
- Right side neck pain with intracranial noise
Fluid Attenuated Inversion Recovery (FLAIR)
- T2WI with suppression of CSF signal
- Increased sensitivity for paraventricular lesions:
  - Ischemic foci
  - Demyelinating plaques

42 y/o Hispanic Woman
- Previous bout of optic neuritis, OS
- H/o RR-MS
43 y/o AA Woman

- c/o progressive left proptosis
- h/o chronic sinusitis
Fat Suppression

- Short tau inversion recovery (STIR)
- Fat saturation (FS)
  - Orbits
  - Neck
  - Bone marrow
Paramagnetic Contrast Enhancement

- Gadolinium (Gd-DTPA)
- Breakdown of blood-brain barrier
  - Edema
  - Vascularization
- Hyperintensity on T1 (shortens T1 signal)

FLAIR T1 Post Gad
71 y/o AA Man

- Progressive vision loss OD > OS (months to years?)
- BVA:
  - LP OD
  - 20/60 OS
74 y/o AA Woman

- Consult for optic atrophy OU
- S/P thyroidectomy for thyroid CA (Rx Tyrosint® (levothyroxine) for hypothyroidism)
- + HTN / DM (advanced renal disease)
- c/o progressive vision loss OS > OD (x 2-3 months)
- Notices left eye protruding (x 2-3 months)
- Left side tinnitus (x 2-3 months)
One thing you should never do is drink a few glasses of Ciroc vodka at an open bar event and then have a glass of straight Hennessy afterwards on a school night.

Diffusion-Weighted Imaging

- Variant of T2WI
- Assessment of the ability of water molecules to freely move (diffuse) within biological tissue (“Brownian motion”)
- Within white matter, water molecules show a linear diffusion parallel to axonal fibers

Hagman P, et al. RSNA 2006
Diffusion-Weighted Imaging

- Acute stroke → translocation of water from the extracellular to the intracellular compartment, where water mobility is relatively more restricted (cytotoxic edema)
- Restricted diffusion = hyperintensity on DWI

DWI (cont.)

- Immediate detection of cerebral ischemia
  - Increased signal intensity within minutes
  - Maximal signal intensity within 2-4 days
  - Slow return to baseline

Apparent Diffusion Coefficient

- Chronicity of stroke:
  - Acute infarct (cytotoxic edema) = low ADC
  - Subacute/chronic infarct (vasogenic edema) = high ADC

  “T2 Shine Through”
9/25/2018

46 y/o Hispanic Man

- Evaluation of optic atrophy OU
- H/o diabetes and hypertension
- BVO:
  - 20/20 OD
  - 20/20 OS
- Recent-onset tremor, confusion, depression, lower left facial weakness and eye tracking problems (impaired saccades greater looking to left)
12 y/o AA Male

- C/o decreased vision, OS x 1 week
- BVA:
  - 20/20 OD
  - 20/60 OS
- RAPD OS
- Pain on eye movement
• Metallic implants can substantially degrade MRI image quality or in certain instances, render the procedure unsafe (e.g. guide wires, aneurysmal clips, pacemakers)

• SOFT TISSUE
• POSTERIOR FOSSA
• SAGITAL PLANE
• DEMYELINATION / MS
• CHRONICITY OF STROKE

• $$$
• LONGER TIME
• CONTRAINDICATED WITH METAL, PREGNANCY & OBESITY
“The chiasm lives in a tough neighborhood.”

Lawrence G. Gray

Sagittal CHIASM PITUITARY Suprasellar Cistern
Chiasmal lesion — pressure from below as in pituitary adenoma.

- Visual field loss
  - Bitemporal hemianopia
  - Denser above than below
  - Progression to entire hemifield
  - Classic for pituitary adenoma

Posterior chiasmal lesion

Insult from above rather than below
Macular fibers cross most posteriorly in the chiasm.

Third ventricle of the chiasm.

Visual field loss

- Posterior chiasmal lesions (pressure from above) deeper below than above.
- Produce bitemporal hemianopia with highest density pointing toward fixation.

Retinal quadrants

- Nasal Macular fibers cross in the most posterior part of the chiasm.

$\text{Visual field loss}$
Lesions of the Chiasm

49 y/o AA woman

• “blurry vision” x 2 weeks
• Dull headache (treated for sinusitis but with no improvement in HA)
• Recently diagnosed with hypothyroidism (treated with Synthroid)
• Elevated prolactin
• BCVA: 20/20 OD, 20/25 OS
Epidermoid Cysts

- < 2% of all intracranial tumors
- Peak incidence 2nd to 5th decades
- Predilection for sellar/parasellar region (emanation from third ventricle)
- Cystic with no enhancement
- Recommended Tx = surgical resection if symptomatic/endocrine dysfunction
- 24% recurrence rate

Discharge & Follow-up

- BCVA: 20/20 OU
- Normalization of visual fields
- Normalization of endocrine function

Pituitary Adenomas

- Benign tumors of pituitary origin
- Third most common intracranial tumor (25% prevalence at autopsy/MRI)
- Micro vs. macroadenoma (>10mm)
- Secretory (prolactin) vs. non-secretory
- Localized (2/3) vs. invasive (1/3)
- Do not produce papilledema
Pituitary Adenoma (cont.)

- MRI findings:
  - Iso-intense to brain
  - Homogenous staining with gadolinium (highly vascularized)

Pituitary Adenoma (cont.)

- Complications:
  - Endocrine dysfunction
  - Pituitary apoplexy
  - Vision!!

40 Y/O Caucasian Man

- C/o progressive side-vision loss, both eyes
- Several months duration
- BVA:
  - 20/20 OD
  - 20/20 -2 OS
61 Y/O Hispanic Woman

- C/o progressive vision loss, both eyes
- Approx. 2 years duration
- BVA:
  - 20/40 OD
  - 20/70 OS
Anterior Chiasmal Syndrome

Anterior genu
Wilbrand
Optic nerve
61 Y/O Hispanic Man

- C/o progressive vision loss, OS
  - Several months duration
- Long-standing history of DM / HTN
- Conf fields:
  - Temp field loss denser above, OD
  - Complete temp field loss, OS
- BVA:
  - 20/20 OD
  - 20/400 OS
S/P Trans-sphenoidal Resection of Tumor

- BVA:
  - 20/20 OD
  - 20/20 OS

79 y/o AA Man

- C/o progressive vision loss OS x several years
- BVA:
  - 20/20 OD
  - 20/60 OS
Rathke’s Cleft Cyst

- Benign, cystic tumors from embryonic remnant of Rathke pouch (33% of autopsy specimens)
- Often with mucin-derived nodule (iso/hyperintense to brain)
- Amenable to transphenoidal drainage
- Variable recurrence

39 y/o Hispanic Woman

- C/o progressive vision loss, OS x several months
- BVA:
  - 20/60 OD
  - 20/20 OS
- + RAPD OD
- Visual fields...
Invasive Pituitary Adenomas

• 35% of all pituitary adenomas
• Invasion of parasellar regions:
  – Vascular (cavernous sinus
  – Neural tissues
  – Bone
• Rapid growth/early recurrence (within 6 months of removal)


44 y/o AA Man

• Progressive vision loss OD x 4 years
• s/p transphenoidal resection of “pituitary mass” in 2014
• BVA:
  – HM OD
  – 20/30 OS
Retro-chiasmal Lesions

70 y/o AA Woman

- C/o progressive difficulty seeing objects to her right x 4 months
- BVA:
  - 20/20 OD
  - 20/20 OS
Lesions behind the chiasm cause binocular visual field defects... homonymous, contralateral.
Retrochiasmal lesions result in binocular visual field defects...
  homonymous, contralateral

Temporal lobe lesion
  Superior retinal quadrants
  Related neurologic problems: Memory/auditory dysfunction, seizures

Parietal lobe lesion
  Superior retinal quadrants
  Related neurologic problems: Neglect of non-dominant side, agnosia, apraxia, math difficulty, abn. saccades
Blood Supply to Occipital Lobes

- P3/P4 branches of the posterior cerebral artery (medial aspect)
  - Calcarine branch
  - Posterior lateral PCA branch

- Middle cerebral artery (lateral aspect)
  - Deep optic branches
**Middle Cerebral Artery—Cortical areas**

- Posterior Cerebral Artery Segments:
  - P1: Brainstem / cortical
  - P2: P3, P4
  - P3: Only cortical excluding calcarine
  - P4: Including calcarine

**Posterior Cerebral Artery**

- Basilar
- Visual cortex
- Middle temporal branches
- Middle temporal branches
- Superior and inferior frontal branches (motor)
- Inferior parietal branches
- Frontal branches
- Occipital branches
- Temporal branches
- Insular branches

**Middle Cerebral Artery**

- Deep
Posterior Cerebral Artery Infarction

- 5-10% of cerebral infarcts
- 5% stroke-related death (P1 & P2 segments)
- 84% chronic visual field defects (P3 & P4 segments)

A 58-y/o Man

- C/o recent onset vision loss on left side
- BVA: 20/20 OU
- PMI: HTN x 20 years
- **Visual fields & MRI:**

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80 y/o Hispanic Man

- Decreased vision OU x 10-12 months
- Difficulty seeing objects to right (conf. fields)
- PMHx:
  - + HTN x “many years”
  - “3 small strokes”
  - Problems with balance/dizziness
- Recent exam for new glasses BVA:
  - 20/50 OD
  - 20/60 OS
34 y/o AA Woman

- Medical history = sickle cell disease (HbSS)
- Suffered stroke in 2007 with complete loss of vision OU
- BVA:
  - 5/200 Feinbloom OD
  - 3/200 Feinbloom OS
- Fundii: Essentially normal
- Visual fields: cannot perform
56 y/o Latino Man

- C/o difficulty seeing objects up & to his right
- BVA:
  - 20/20 OD
  - 20/20 OS
- Occasional HA
The Rest of the Story...

• Treated for gonorrhea 30 yrs. ago
• Serology:
  – + FTA-Abs
• CSF:
  – Protein (86.7 mg/100 ml)
  – IgG (14.7 mg/100 ml)
  – IgM (2.0 mg/100 ml)
  – + VDRL

CNS Syphilitic Vasculitis

• Positive FTA-Abs / CSF VDRL
• Elevated protein and pleocytosis
• Commonly along distribution of middle cerebral artery (less often with basilar artery distribution)
• IV cephtriaxone (2g/day x 21 days)
• Antiplatelet Tx (clopidrogel & aspirin)

46 y/o AA Man

• C/o difficulty seeing objects up & to his right (approx. 6 mos)
• Right side hemiparesis
• + HIV & syphilis
• BVA:
  – 20/20 OD
  – 20/20 OS
44 y/o AA Man

- C/o difficulty seeing objects down & to his right
- + epilepsy
- BVA:
  - 20/20 OD
  - 20/20 OS
Occipital Lobe Arteriovenous Malformations

- Occipital epilepsy
  - Flashes of light
  - Homonymous field defects (dimming)
- Occipital apoplexy (acute hemorrhage)
  - Sudden onset headaches
  - Homonymous field loss
- Confusion with migraine

Clinical Findings

- Homonymous visual field defects
- Flashing lights
- Headache
- Seizures
Treatment Options

• 30% natural risk of hemorrhage
  – Resection
  – Radiosurgery
  – Embolization
  – Observation

Yang Y. et al. Neurosurgery 2014

Key Points

• Imaging techniques and scan selection
• Correlative neuroanatomy and neuroradiology for visual pathway lesions
  – Chiasm
  – Retro-chiasm

Thank you!