Non-Interpretive Skills

Clinical Neuroradiology Primer
Before You Begin

This module is intended primarily for **clinical medical students or interns** intending to learn or review non-interpretive radiology skills.

Please note that while not integral, this module series assumes some familiarity with basic imaging techniques and interpretive skills. If you wish to learn or review these concepts, please see our “Interpretive Skills” module series.

If material is repeated from another module, it will be outlined as this text is so that you are aware
Goal

Make you an educated consumer of neuroimaging
Outline

• *Know the tools* at your disposal (CT, MRI, contrast) and when to use them

• *Construct* appropriate *imaging algorithms* for common diagnostic scenarios
Techniques
Neuroradiology Techniques

**Anatomic Imaging**
- Radiographs
  - CT
  - MRI

**Physiologic Imaging**
- Perfusion
- Functional MRI (fMRI)
- Magnetic Source Imaging (MSI)
- PET/MRI

**Vascular Imaging**
- Ultrasound
- CTA
- MRA
- Digital subtraction angiography

**Procedures**
- Spine biopsy and therapy
- Head & Neck biopsy
- Neurointerventional (DSA/endovascular)
Techniques: CT

Brain Window

Bone Window
Techniques: CT

Key term: Density (attenuation)

Absolute scale measured in Hounsfield Units (HU)
Do We Really Need to Thank the Beatles for the Financing of the Development of the Computed Tomography Scanner?

Zeev V. Maizlin, MD* and Patrick M. Vos, MD†

Sir Godfrey Hounsfield (1919 – 2004) with EMI scanner, won the Nobel Prize in 1979
Techniques: CT

**CT Indications**
- Trauma – fractures, hemorrhage
- Stroke
- Hydrocephalus
- Mass effect/Herniation
- Bones/calcification
- Acute infection/inflammation

**Advantages**
- Availability
- Fast acquisition
- Great for acute blood and bones

**Disadvantages**
- Ionizing radiation
- Poor soft tissue resolution relative to MRI
Techniques: CT

What’s CT good for? HHH, LVTI

Hemorrhage  Herniation  Hydrocephalus  Large Vessel Territory Infarct
Techniques: MRI

magnetic field
(Static 'B0' + gradients)
Techniques: MRI

Key term: Intensity

Relative scale, meaning depends on the sequence
Techniques: MRI

T2: Fluid sensitive
Techniques: MRI

T2: Fluid sensitive

CSF is bright

FLAIR: Fluid sensitive (T2), but CSF signal is suppressed

CSF is dark
Techniques: MRI

**MRI Indications**
- Tumor, inflammation, infection
- Stroke
- Chronic conditions (epilepsy, headache, dementia)
- Cranial nerve/skull base disease

**Advantages**
- Great tissue contrast
- Specific sequences answer specific questions
- No ionizing radiation

**Disadvantages**
- Cost/availability
- Main magnet always on
- Metal artifacts
- Long exams, need to be still
- Small bore = claustrophobia
Techniques: MRI

What's MRI good for?

Tumor
Infection
Stroke
Epilepsy

and much more...
Common scenarios
Echo, Trauma
- 117 yo M, unrestrained passenger in MVC
- GCS 7
- Scalp lacerations
Echo, Trauma: 117 yo M unrestrained passenger in MVC, GCS 7, Scalp lacerations

What are you most concerned about?

Head Trauma
- Bleed – epidural, subdural, contusion
- Fracture – calvarial, skull base, facial

What tools can you use?

CT
- Pros
- Cons
MRI
- Pros
- Cons
Contrast?

What do you order?

Non-contrast head CT

Key point: Non-contrast CT in head trauma – fast, available, sensitivity for blood/fractures
**Head Trauma**

**TABLE 38-2**

<table>
<thead>
<tr>
<th>BEHAVIOR</th>
<th>RESPONSE</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye opening</td>
<td>Spontaneously</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>To speech</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>To pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>1</td>
</tr>
<tr>
<td>Best verbal</td>
<td>Oriented to time, place, and person</td>
<td>5</td>
</tr>
<tr>
<td>response</td>
<td>Confused</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Inappropriate words</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Incomprehensible sounds</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>1</td>
</tr>
<tr>
<td>Best motor</td>
<td>Obeys commands</td>
<td>6</td>
</tr>
<tr>
<td>response</td>
<td>Moves to localized pain</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Flexion withdrawal from pain</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Abnormal flexion (decorticate)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Abnormal extension (decerebrate)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total score:**
- Best response = 15
- Comatose client = 8 or less
- Totally unresponsive = 3

**Moderate to severe impairment**
- Noncontrast CT

**Mild impairment (GCS ≥ 13)**
- ???
  - Canadian Rule
  - New Orleans Criteria
  - NEXUS Criteria
NEXUS Criteria

For patients with GCS 13-15 after witnessed traumatic loss of consciousness, CT is only required for patients with any of the following findings:

<table>
<thead>
<tr>
<th>High risk for neurological intervention</th>
<th>Medium risk for brain injury detection by CT imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GCS &lt;15 at two hours after injury</td>
<td>1. Amnesia before impact of 30 or more minutes</td>
</tr>
<tr>
<td>2. Suspected open or depressed skull fracture</td>
<td>2. Dangerous mechanism‡</td>
</tr>
<tr>
<td>3. Any sign of basal skull fracture†</td>
<td></td>
</tr>
<tr>
<td>4. Two or more episodes of vomiting</td>
<td></td>
</tr>
<tr>
<td>5. ≥65 years of age</td>
<td></td>
</tr>
</tbody>
</table>

Exclusion criteria: no history of trauma, GCS <13, age <10 years, warfarin use or coagulopathy, obvious open skull fracture.

† Hemotympanum, raccoon eyes, cerebrospinal fluid, otorrhea or rhinorrhea, and Battle’s sign.
‡ A pedestrian struck by motor vehicle, an occupant ejected from a motor vehicle, or a fall from an elevation of ≥3 feet or 5 stairs.
Spectrum of Intracranial Hemorrhage

Epidural  Subdural  Subarachnoid  Subarachnoid  Intraparenchymal
Rigby, Eleanor
• 79 yo F, right facial droop and aphasia
Rigby, Eleanor: 79 yo F right facial droop and aphasia

**What are you most concerned about?**
- Stroke
  - Ischemic
  - Hemorrhagic

**What tools can you use?**
- CT
  - Pros
  - Cons
- MRI
  - Pros
  - Cons
  - Contrast?
  - Angiography?

**What do you order?**
- Stroke protocol CT:
  - Non-con head CT
  - CT perfusion
  - CT angiography head and neck

**Key point:** Trade-off between CT and MRI in stroke evaluation
Focal Neurologic Deficit

Noncontrast CT

CT perfusion
CTA
Post-contrast

IV tPA if eligible:
- within window
- no bleed, large infarct

Endovascular therapy if warranted

MRI
Diffusion, Perfusion

MRA COW and neck (if CTA not performed)

Follow-up CT
Focal Neurologic Deficit
Perfusion Imaging

- Image labeled blood moving through tissue to measure blood flow/volume
- Can show ‘hypo-perfused’ issue at risk for ischemia
- CT and MRI versions

MRI Dynamic Susceptibility Contrast-Enhanced (DSC) Perfusion
Perfusion Imaging in acute stroke

Blood volume

Time (blood flow)

High

Low

Matched defect = dead/infarcted tissue

Mismatched defect = tissue at risk, 'penumbra'
Focal Neurologic Deficit

Findings:
CTP shows large mismatched defect in MTT and CBV suggesting large area of tissue at risk ('penumbra')
Findings:

CTA shows Left MCA M1 cutoff (clot)
FOLLOW UP CT AND MR (DWI)

Findings:
Small Left BG infarct

MTT
Smith, Tim
- 33 yo M, first time seizure
- No sig past medical
Smith, Tim: 33 yo M first time seizure, no significant past medical history

**What are you most concerned about?**
- Mass lesion
  - Tumor
  - Infection
  - Inflammation
  - Hemorrhage

**What tools can you use?**
- CT
  - Pros
  - Cons
- MRI
  - Pros
  - Cons
  - Contrast?

**What do you order?** MRI w/ contrast vs. CT first
- What if 2 year old with a fever?
- What if 78 year old with a history of colon CA?

**Key point:** Consider age and clinical context
Mass Lesions on Contrast-enhanced MRI

Demyelination, Metastasis, Abscess, Hematoma, Radiation Necrosis

Difficult to differentiate on one sequence alone!!
Williamsburg, Dolores

- 29 yo F, WHOL
- No sig past medical
Williamsburg, Dolores: 29 yo F worst headache of life x 24 hrs

What are you most concerned about?
Subarachnoid hemorrhage

What tools can you use?
CT
• Pros
• Cons
MRI
• Pros
• Cons
Contrast?

What do you order?
Non-con head CT
Noncontrast CT

Findings:
Right TPO region IPH

CTA/CTV Head

Findings:
Right Trans Sinus Thrombosis
Treatment? IV Heparin
Where’s the hemorrhage?

sensitivity of CT for SAH: >95% if < 24 hrs
70% @ 3 days
50% @ 1 wk

CSF xanthochromia peaks @ 2-4 days

Isodense SDH
Williamsburg, Dolores: 29 yo F worst headache of life x 24 hrs

What are you most concerned about?
- Subarachnoid hemorrhage
- What if patient additionally had a fever?
- Infection

What tools can you use?
- CT
  - Pros
  - Cons
- MRI
  - Pros
  - Cons
  - Contrast?

What do you order? Non-con head CT
 If patient also had a fever? MRI with contrast

Key points:
- Blood on CT: timing = Sensitivity
- Next step: depends on suspected cause
Where’s the finding?

Subdural empyema
Wu, Scott
- 33 yo M, HA, sinus pain, and drainage
- No sig past medical
Wu, Scott: 33 yo M chronic sinus pain and drainage

What are you most concerned about?

Sinus disease
- Acute
- Chronic
- Special case – Acute invasive fungal

What tools can you use?

CT
- Pros
- Cons
MRI
- Pros
- Cons
Contrast?

What do you order?

Non-con sinus CT
Contrast enhanced MRI face/sinus
Findings:

Acute maxillary sinus disease

Chronic maxillary sinus disease
Star, Jennifer

- 35 yo F, HA, sinus pain, and drainage
- Hx ALL sp stem cell Tx
Non con CT

Contrast enhanced MRI

Findings:
Invasive fungal sinusitis with necrosis
Alpha, Trauma

- 70 yo F, found down
- GCS 14
- Severe back pain, upper and lower extremity weakness
Alpha, Trauma: 70 yo M found down, GCS 14, severe back pain, UE and LE weakness

What are you most concerned about?

Spine trauma
  - Fracture
  - Malalignment
  - Ligamentous injury
  - Cord compression/injury
  - Cauda Equina syndrome

What tools can you use?

CT
  - Pros
  - Cons

MRI
  - Pros
  - Cons

Contrast?

What do you order?

CT cervical spine without contrast
What would you order next?

Non-con CT

Non-con MRI T1

Non-con MRI T2
Spine trauma: 3 column model of spine stability

Ant. column
Ant Longit Lig
Ant annulus
Ant 2/3 vert body

Middle column
Post 1/3 of vert body
Post annulus, Post Longit Lig

Post. column
Posterior elements
- pedicles, facets,
- lamina
- spinous process
- posterior ligaments

Ant comp fx
stable

Burst fx
unstable

unstable = involvement of 2 adjacent columns
Smith, Clarence
• 65 worsening back pain following move
• Neurologically intact
Smith, Clarence: 65 worsening back pain following move, neurologically intact

**What are you most concerned about?**
- Spine trauma
  - Fracture
  - Malalignment
  - Ligamentous injury
  - Cord compression/injury
  - Cauda Equina syndrome

**What tools can you use?**
- CT
  - Pros
  - Cons
- MRI
  - Pros
  - Cons
  - Contrast?

**What do you order?**
- Nothing

**Key point:** Consider appropriateness criteria/guidelines
Joint guidelines from the American College of Physicians (ACP) and the American Pain Society explicitly recommend that "**clinicians should not routinely obtain imaging or other diagnostic tests in patients with nonspecific low back pain**" … reserve imaging for patients with severe or progressive neurologic deficits or when serious underlying conditions are suspected on the basis of history and physical examination [17,18].

Guidelines from the National Institute for Health and Care Excellence (NICE) in the United Kingdom advise clinicians to “not routinely offer imaging in a non-specialist setting for people with low back pain with or without sciatica” [72].

**Evaluation of low back pain in adults**
Wheeler et al. UpToDate
Charlie, Trauma

- 65 yo F, fall from ladder
- GCS 14
- Back pain, lower extremity weakness, urinary incontinence
Charlie, Trauma: 65 yo F fall from ladder, GCS 14, back pain, LE weakness, urinary incontinence

What are you most concerned about?

- Spine trauma
  - Fracture
  - Malalignment
  - Ligamentous injury
  - Cord compression/injury
  - Cauda Equina Syndrome

What tools can you use?

- CT
  - Pros
  - Cons
- MRI
  - Pros
  - Cons
  - Contrast?

What do you order?

- MRI spine without contrast
Doe, Jane
- 37 yo F, IVDU
- fever, low back pain
Doe, Jane: 37 yo F IVDU, fever, low back pain

What are you most concerned about?
- Spine trauma
- Infection

What tools can you use?
- CT
  - Pros
  - Cons
- MRI
  - Pros
  - Cons
  - Contrast?

What do you order?
- MRI lumbar spine with contrast

Key point – Patient population can determine modality
Findings:
Discitis-osteomyelitis with epidural abscess
Outline

- *Know the tools* at your disposal (CT, MRI, contrast) and when to use them

- *Construct* appropriate *imaging algorithms* for common diagnostic scenarios
Goal

Make you an educated consumer of neuroimaging
A patient with no known medical history presents with altered mental status (GCS 9). What is the most appropriate initial study to order:

A. CT of the head WITH contrast
B. CT of the head WITHOUT contrast
C. Plain films of the skull
D. MRI of the head WITH contrast
E. MRI of the head WITHOUT contrast
Question 1

A patient with no known medical history presents with altered mental status (GCS 9). What is the most appropriate initial study to order:

A. CT of the head WITH contrast
B. CT of the head WITHOUT contrast
C. Plain films of the skull
D. MRI of the head WITH contrast
E. MRI of the head WITHOUT contrast
Question 2

A 57-year-old woman presents with periorbital redness and swelling. She gives a history of a recent URI and fevers. What is the best imaging test to order next?

A. Skull radiographs
B. CT without contrast
C. CT with contrast
D. CT angiogram
E. MRI without contrast
A 57-year-old woman presents with periorbital redness and swelling. She gives a history of a recent URI and fevers. What is the best imaging test to order next?

A. Skull radiographs
B. CT without contrast
C. **CT with contrast**
D. CT angiogram
E. MRI without contrast
Question 3

A non-contrast head CT is an appropriate study to evaluate which for which of the following brain pathologies?

A. Infection
B. Tumor
C. Arterial aneurysm
D. Hemorrhage
E. Dural venous thrombosis
A non-contrast head CT is an appropriate study to evaluate which of the following brain pathologies?

A. Infection
B. Tumor
C. Arterial aneurysm
D. Hemorrhage
E. Dural venous thrombosis
Learning Objectives

1. List indications for contrast enhanced CT and MR neuroimaging

2. Construct an appropriate imaging algorithm for common diagnostic scenarios including: suspected stroke, suspected subarachnoid hemorrhage, head and spine trauma, seizures, and sinus disease
END