Neuroimaging Overview

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Objectives

- To list the imaging modalities available for assessment of the brain and spine
- To review the advantages and disadvantages of the various imaging modalities utilized in neuroimaging
- To present examples of normal anatomy of the brain and spine, utilizing radiographs, sonography, computerized axial tomography (CT), magnetic resonance imaging (MRI), and nuclear medicine

Imaging modalities in neuroimaging

- Radiographs
  - Advantage: inexpensive; general initial overview
  - Disadvantage: limited assessment of the brain parenchyma and spinal cord
- Sonography (including Doppler analysis)
  - Advantage: no ionizing radiation; screening of cervical carotid artery systems
  - Disadvantage: limited assessment of brain parenchyma

Imaging modalities in neuroimaging

- CT
  - Advantage: assessment of acute intracranial hemorrhage; optimal osseous assessment in the presence of trauma; CTA capabilities (head/neck)
  - Disadvantage: ionizing radiation; cost; somewhat limited in the assessment of acute cerebral ischemia
- MRI
  - Advantage: assessment of acute cerebral ischemia; exquisitely detailed assessment of brain and spinal cord anatomy; MRA capabilities (head/neck)
  - Disadvantage: cost; not feasible in all patients (i.e. unapproved aneurysm clips; pacemakers)

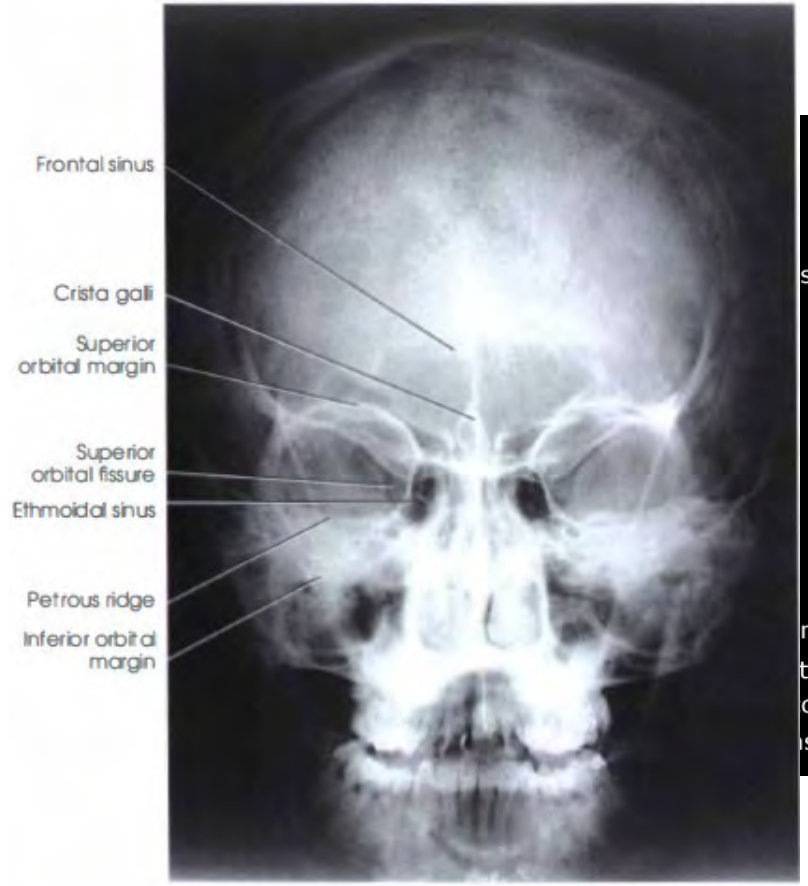
Imaging modalities in neuroimaging

- Nuclear medicine
  - Advantage: functional assessment of CSF flow, cerebral blood flow, potential sites of infection
  - Disadvantage: often supplanted by more advanced modalities (MRI/CT); ionizing radiation; sensitive (but) nonspecific modality

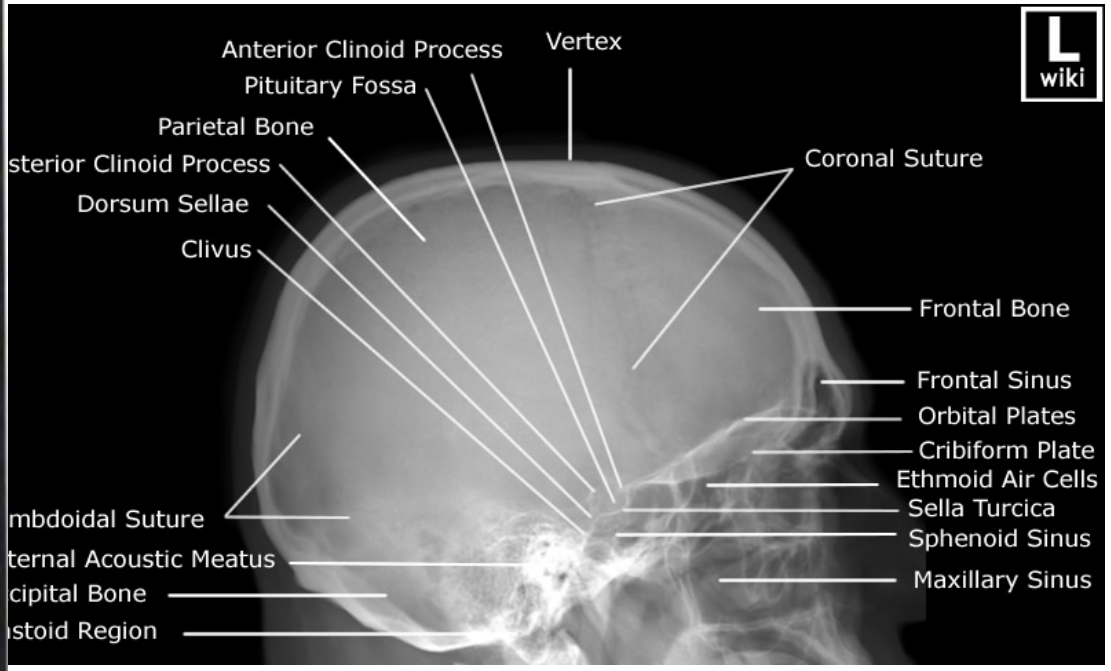
Radiographs

- Radiographs are more useful in assessment of the spinal axis than they are in assessing the skull.
  - In trauma cases, spinal radiographs may be utilized as an *initial* imaging tool (which may be augmented/supplanted by CT and/or MRI imaging)
  - In trauma cases, skull radiographs are of limited value in that they do *not* allow for assessment of underlying brain parenchyma

Normal skull radiograph

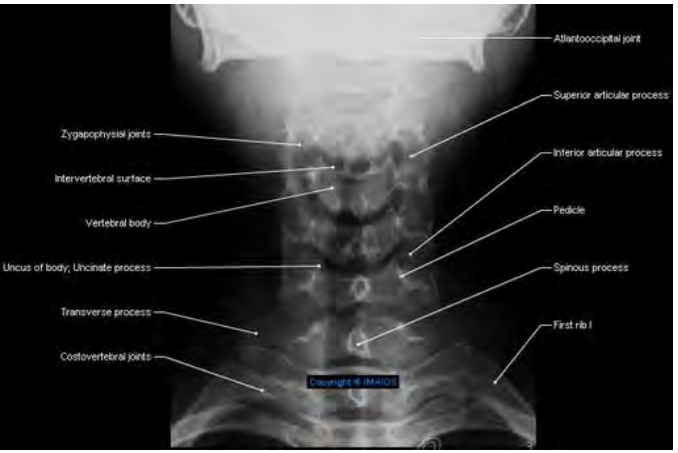


Caldwell projection

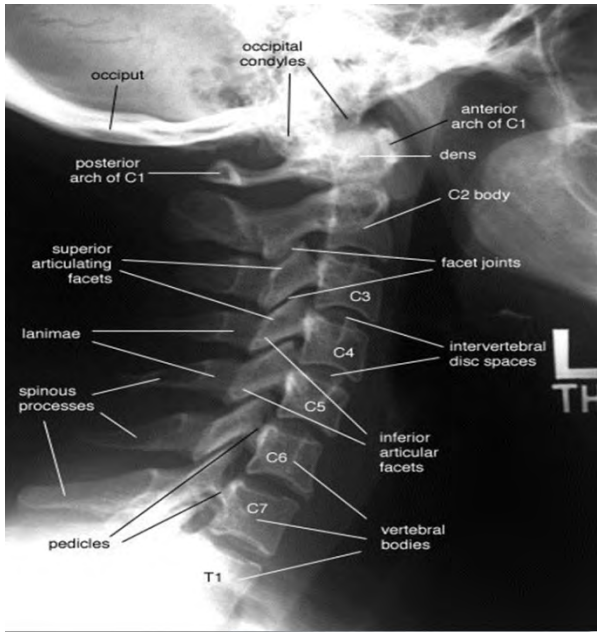


Lateral projection

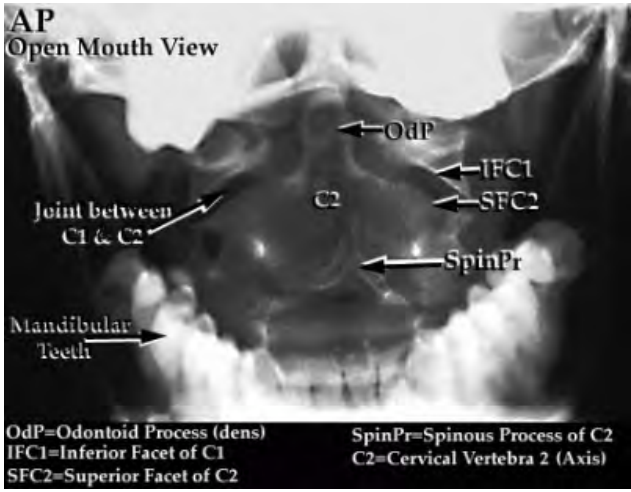
Normal cervical spine series



AP view

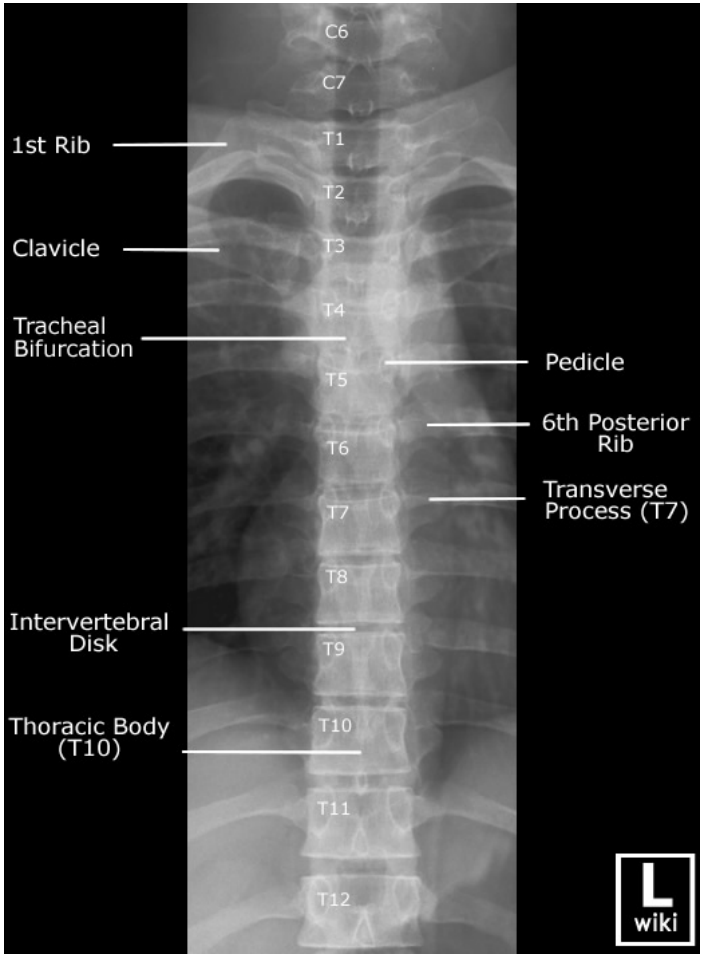


Lateral view



Open-mouth odontoid view

Normal thoracic spine series

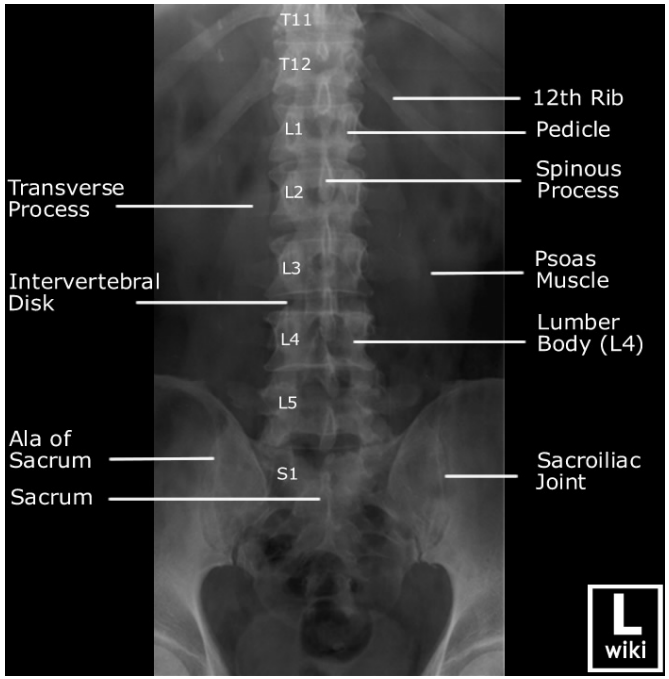


AP projection

Swimmer's projection

Lateral projection

Normal lumbar spine series



AP view

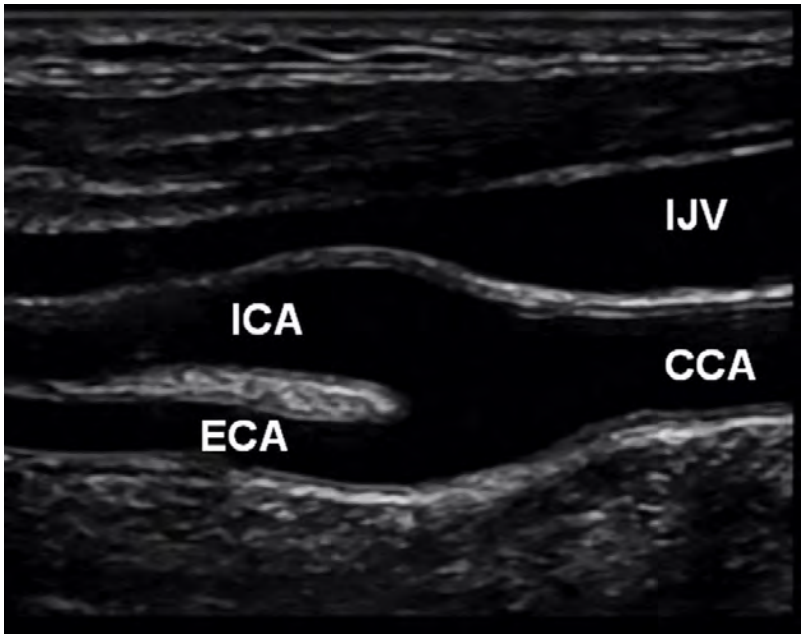
Lateral view

Right oblique and left oblique views

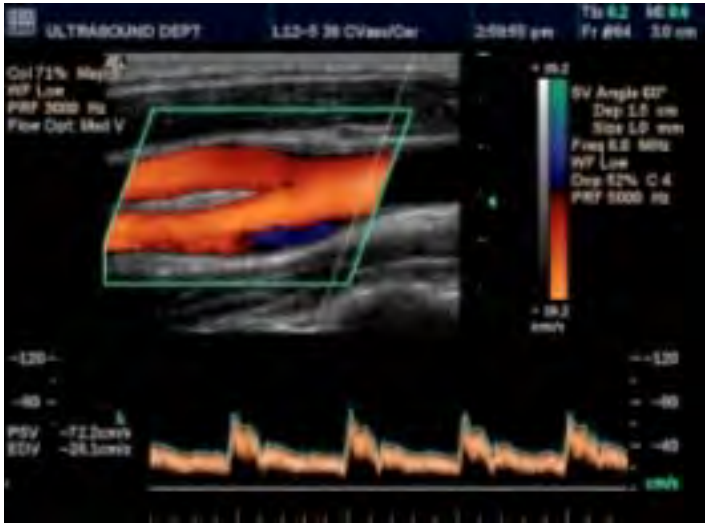
Sonography

- Carotid sonography serves as a *screening* examination for assessment of underlying disease (i.e. most commonly stenosis) of the cervical carotid artery system
- Gray-scale, color flow, and Doppler assessment permits an estimation of the degree of carotid artery stenosis (i.e. cervical segment of the internal carotid artery, ICA)

Normal carotid artery sonogram



Gray-scale



Color flow and Doppler

Computerized axial tomography (CT): head/neck

- Unenhanced head CT
  - Utilized in emergent assessment of ‘stroke-like symptoms’
    - Potentially followed by brain MRI and head/neck MRA
  - Utilized in cases of head trauma
    - Assess for skull fracture, acute intracranial hemorrhage, and cerebral edema

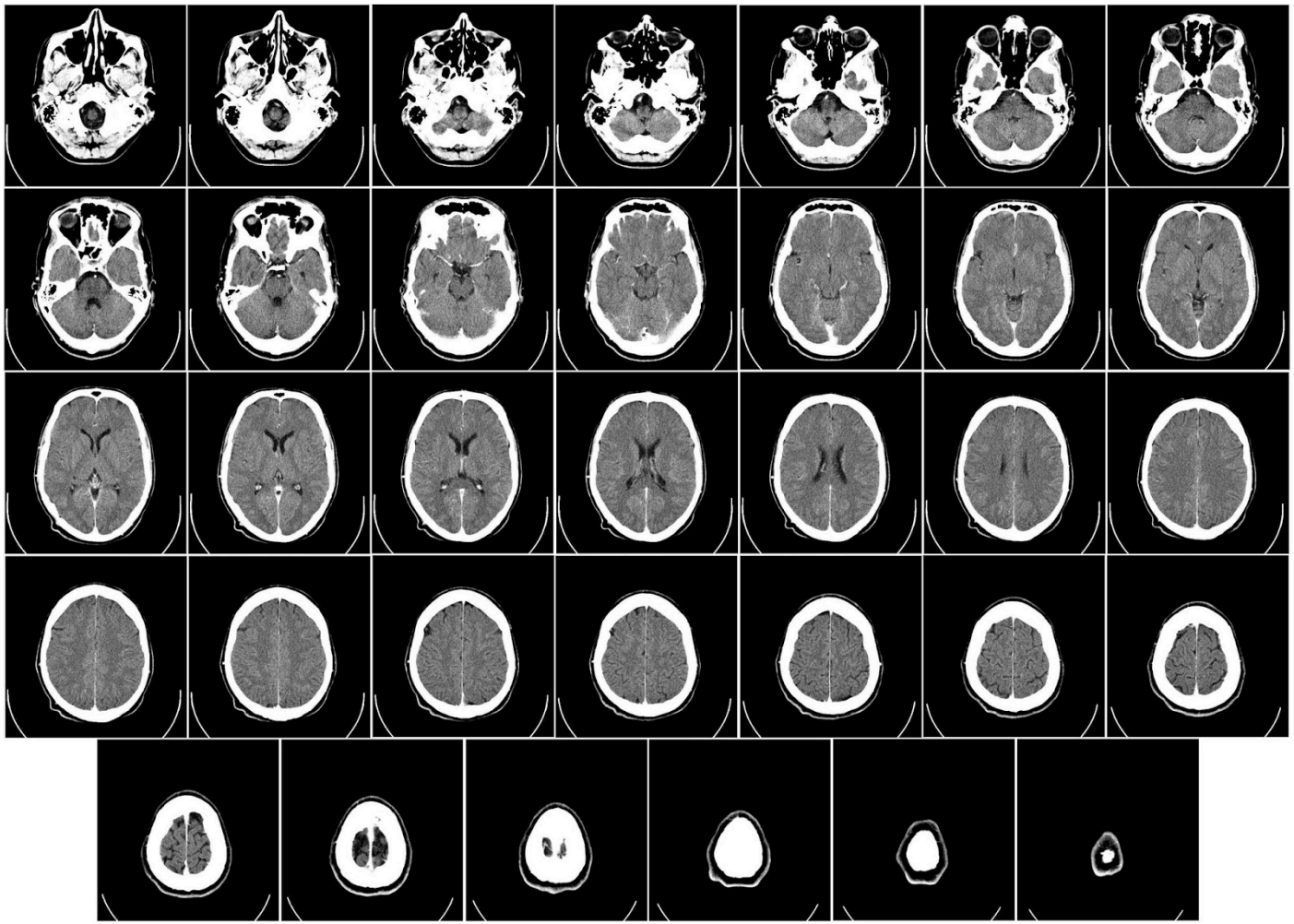
Computerized axial tomography (CT): head/neck

- Enhanced head CT (with IV iodinated contrast)
  - Utilized in the assessment of suspected brain neoplasia (primary or secondary)
    - May be supplanted by MRI
  - Utilized in initial assessment of clinically-suspected infection (i.e. meningitis or cerebritis)
    - May be supplanted by MRI
  - Utilized in initial assessment of non-specific symptomatology of the brain (i.e. congenital abnormalities, demyelinating diseases, neuro-degenerative diseases, etc.)

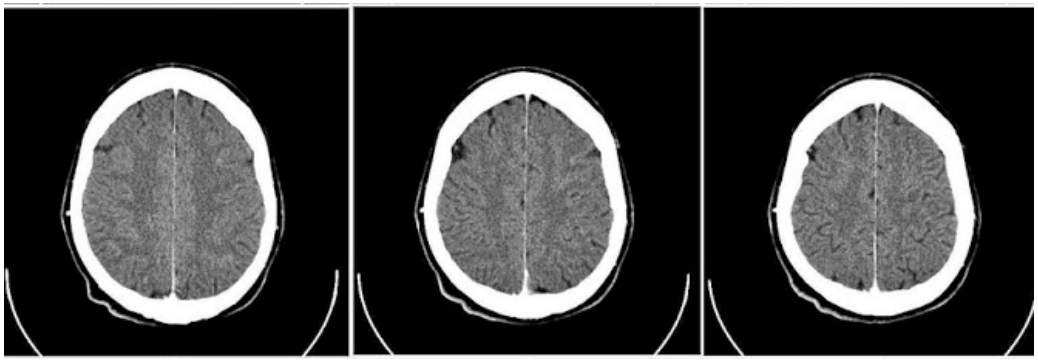
Computerized axial tomography (CT): head/neck

- CTA of the neck; CTA of the head (with IV contrast)
  - Utilized to assess for carotid artery stenosis
  - Utilized to assess for intracranial aneurysms
  - Utilized to assess for other intracranial vascular malformations

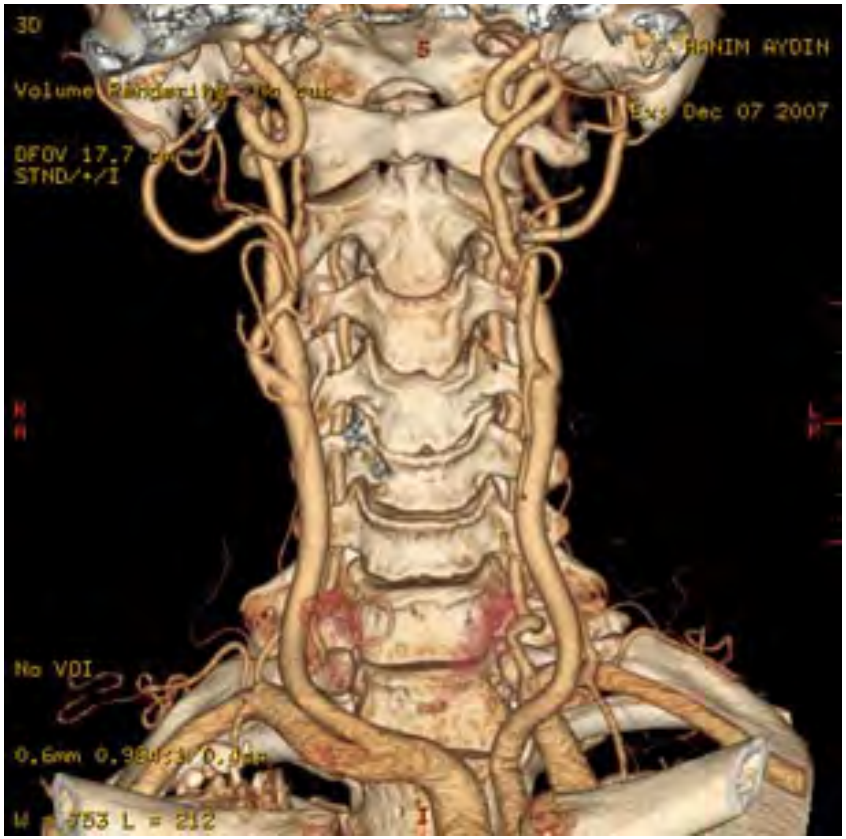
Normal (enhanced) head CT



Normal (enhanced) head CT



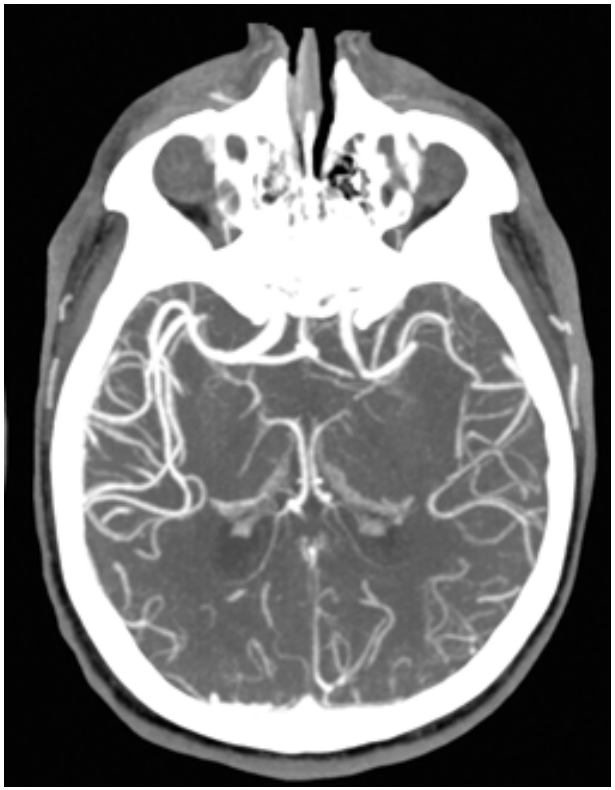
Normal neck CTA



Native data (from neck CTA)

Neck CTA (post-processing)

Normal CTA Circle of Willis



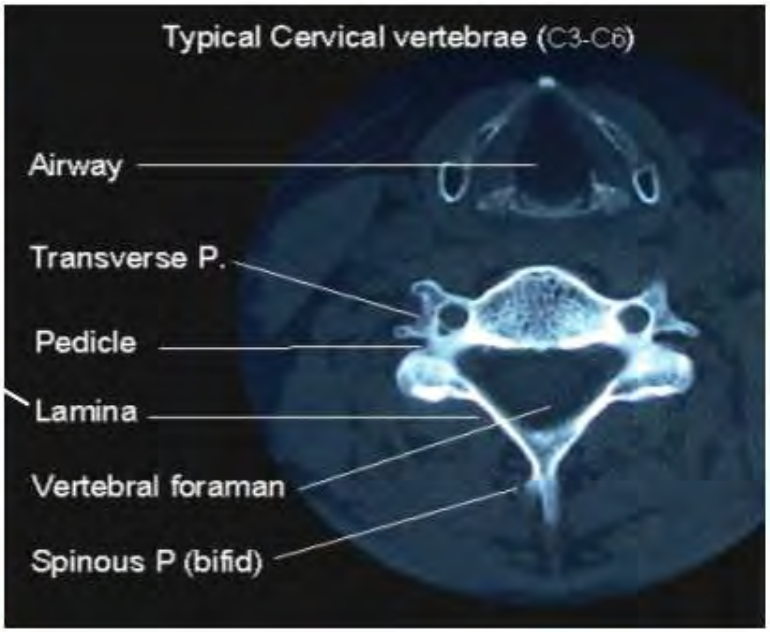
Native data (head CTA)

CTA of C.O.W. (post-processing)

Computerized axial tomography (CT): spine

- Unenhanced CT of the cervical, thoracic, or lumbar spine
  - Utilized in cases of spinal trauma
    - Assess for fracture, traumatic intervertebral disc herniation
- Enhanced spinal CT (with intrathecal iodinated contrast): *CT myelogram*
  - Utilized in the assessment of suspected degenerative disc and degenerative joint
    - May be supplanted by MRI

Normal unenhanced CT cervical spine

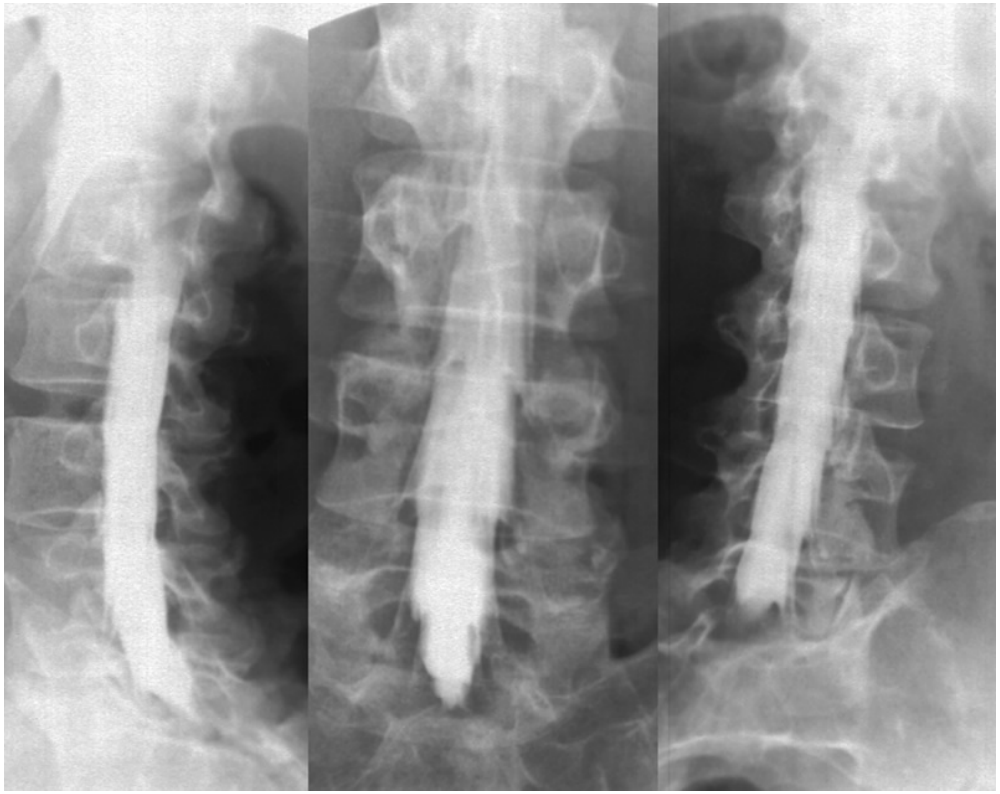


AP projection

Axial image

Sagittal reconstruction

CT myelogram



Pre-CT lumbar myelogram (AP, B/L oblique views)

Sagittal reconstruction (CT myelogram)

Magnetic resonance imaging (MRI): head/neck

- Unenhanced MRI brain
  - Utilized in emergent assessment of ‘stroke-like symptoms’
    - As a follow-up to emergent head CT

Magnetic resonance imaging (MRI): head/neck

- Enhanced MRI brain (with IV gadolinium contrast)
  - Utilized in the assessment of suspected brain neoplasia (primary or secondary)
  - Utilized in initial assessment of clinically-suspected infection (i.e. meningitis or cerebritis)
  - Utilized in initial assessment of non-specific symptomatology of the brain (i.e. dysmyelinating diseases, demyelinating diseases, neuro-degenerative diseases, etc.)

Magnetic resonance imaging (MRI): head/neck

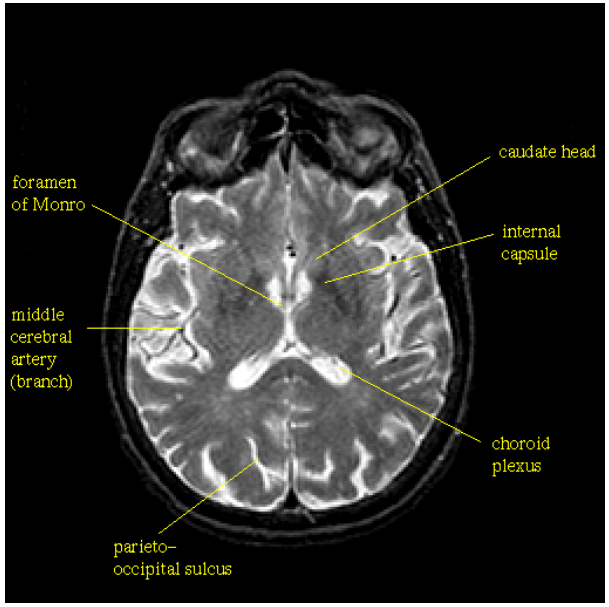
- MRA of the neck; MRA of the head (with IV contrast)
  - Utilized to assess for carotid artery stenosis
  - Utilized to assess for intracranial aneurysms
  - Utilized to assess for other intracranial vascular malformations

Magnetic Resonance Imaging (MRI)

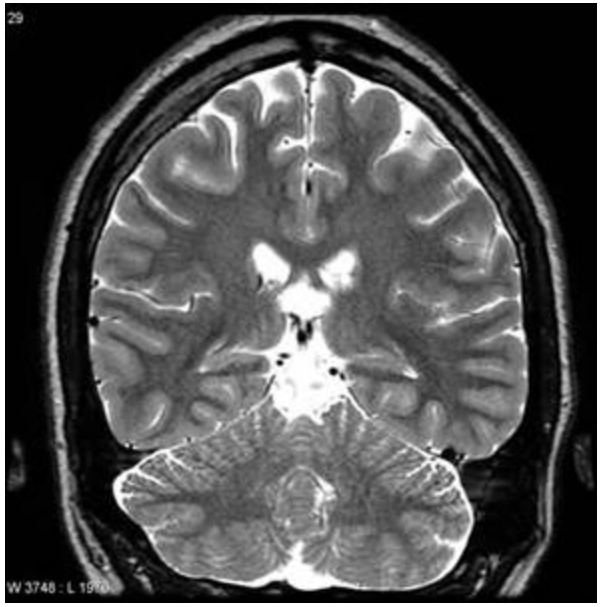
- MRI imaging
  - Terminology: “intensity”
    - *Hyper*intensity: white/bright
    - *Hypo*intensity: black/dark
  - Sequences
    - T1-weighted:
      - fluid is ‘dark’; fat is ‘bright’; white matter is ‘brighter’ than gray matter
    - T2-weighted:
      - fluid is ‘bright’; white matter is ‘darker’ than gray matter
      - T1 and T2 sequences, however, are *not* simply the inverse of one another
    - FLAIR: Fluid-attenuated inversion recovery
      - normal fluid (CSF) is attenuated (nulled); abnormal fluid (edema) as well as gliosis/demyelination is ‘bright’
    - Diffusion-weighted imaging:
      - sites of restricted water movement (i.e. cytotoxic edema) are ‘bright’

Normal unenhanced MRI brain

(T1) sagittal image

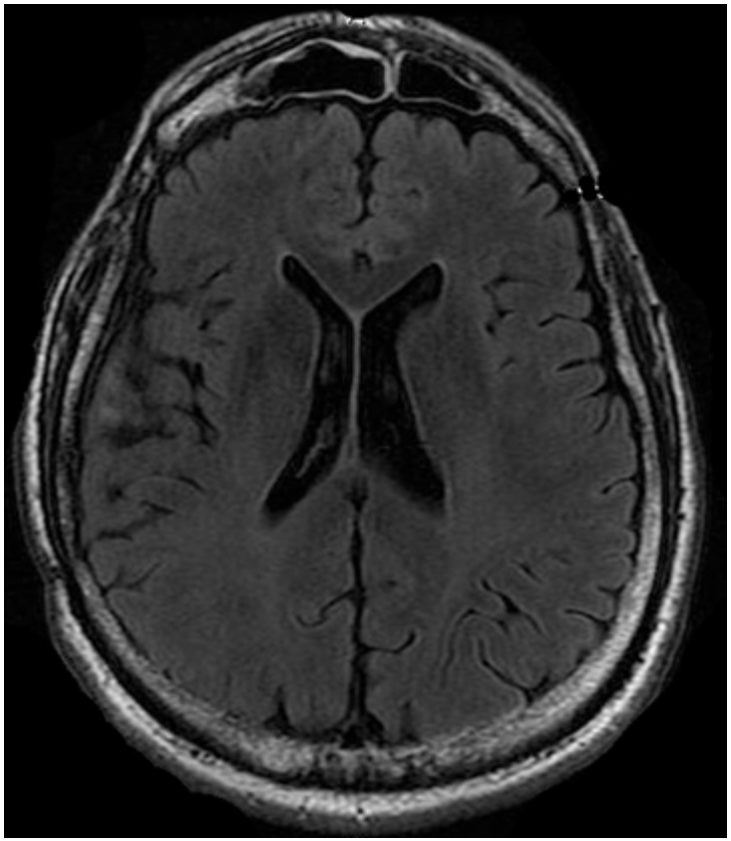


(T2) axial image

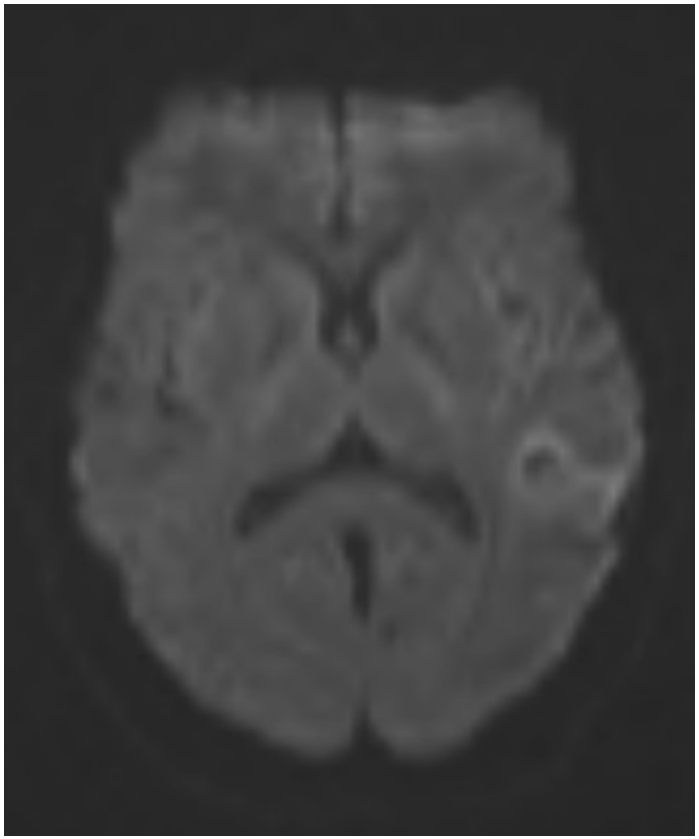


(T2) coronal image

Normal unenhanced MRI brain

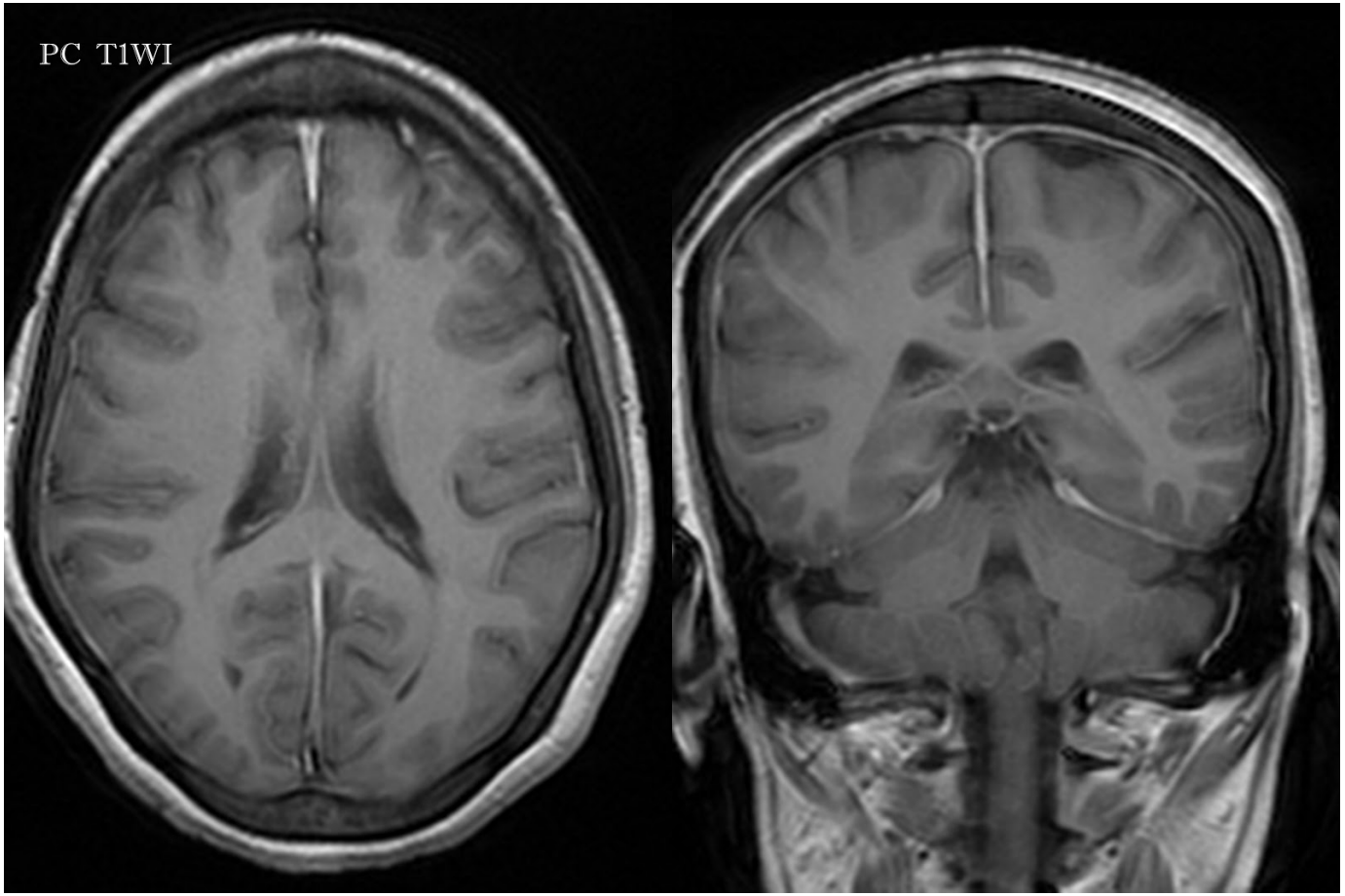


FLAIR axial

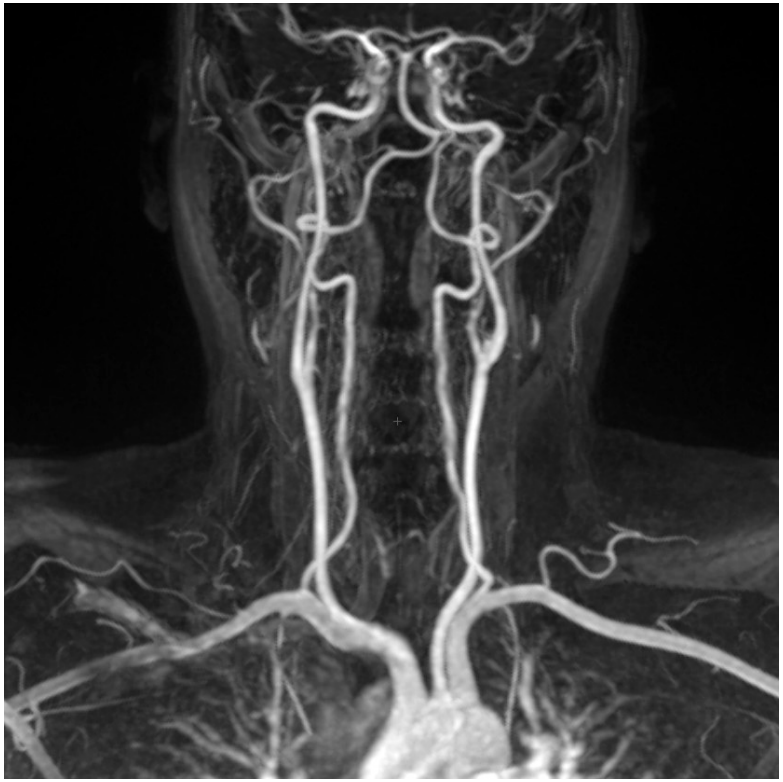


Diffusion-weighted (DWI) axial

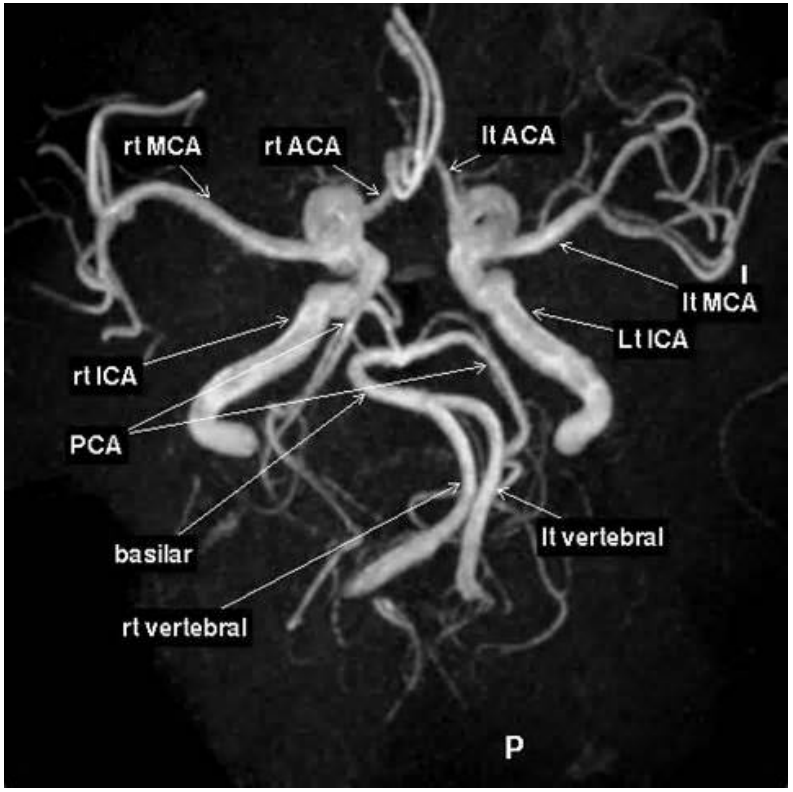
Normal enhanced MRI brain



Normal MRA neck/head



Enhanced MRA, neck (coronal)



Unenhanced MRA, brain

Magnetic resonance imaging (MRI): spine

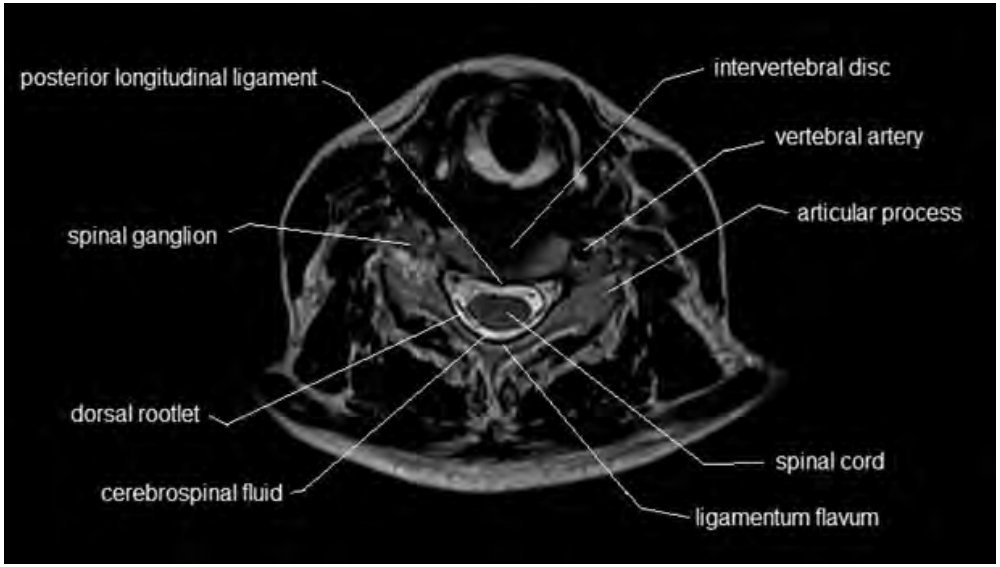
- MRI of the cervical, thoracic, or lumbar spine
  - Utilized in cases of radiculopathy and/or myelopathy
    - Assess for degenerative disc and degenerative joint disease
    - Preoperative assessment
    - Post-operative (serial) assessment (IV contrast)
  - Utilized in cases of spinal trauma
    - Assess for fracture, traumatic intervertebral disc herniation, foci of hemorrhage, cord contusion/edema

Magnetic resonance imaging (MRI): spine

- MRI of the cervical, thoracic, or lumbar spine
  - Utilized in cases of suspected spinal infections (IV contrast)
    - Post-operative patients
    - Patients with sepsis
  - Utilized in cases of suspected spinal metastasis (IV contrast)
    - Cord compressive symptoms
    - Osseous neoplasia
    - Neoplasia involving the cord/nerve roots

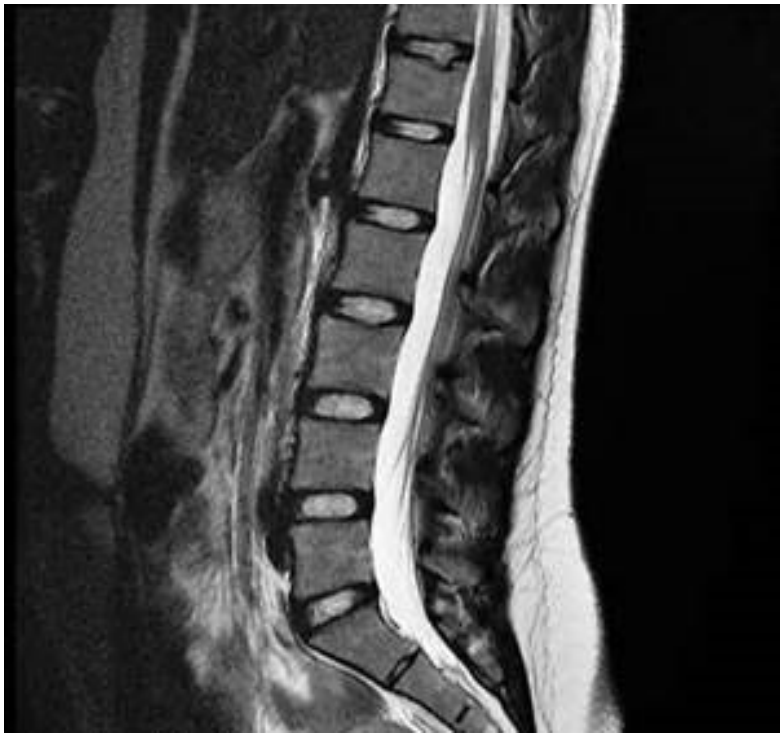
Normal MRI (C-spine)

(T2) sagittal C-spine



(T2) axial C-spine

Normal MRI (L-spine)



(T2) sagittal L-spine

(T2) axial L-spine

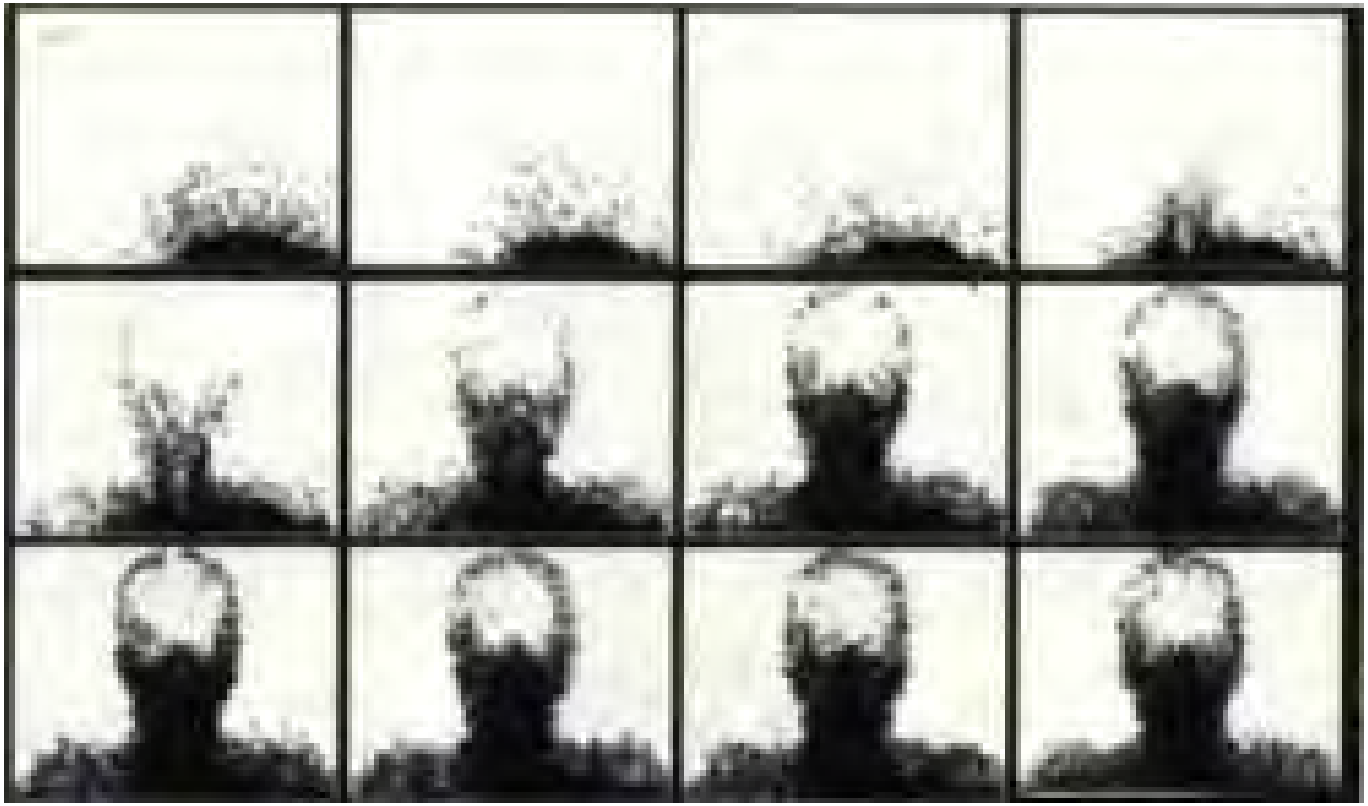
Nuclear medicine

- Allows for functional (and structural) assessment of the neural axis
  - Cerebral blood flow
    - Assists in the clinical assessment of ‘brain death’
      - IV injection of radiopharmaceutical (i.e. Tc-99m DTPA). Assessment presence/absence of dynamic flow within the intracranial ACAs and MCAs
  - Radionuclide cisternogram:
    - Assists in the workup of (normal pressure) hydrocephalus, CSF leak, shunt patency
      - Utilizing lumbar puncture, radiopharmaceutical (i.e. In-111-DTPA) is administered into the CSF space. Serial images of the head allow for analysis of CSF flow dynamics

Nuclear medicine

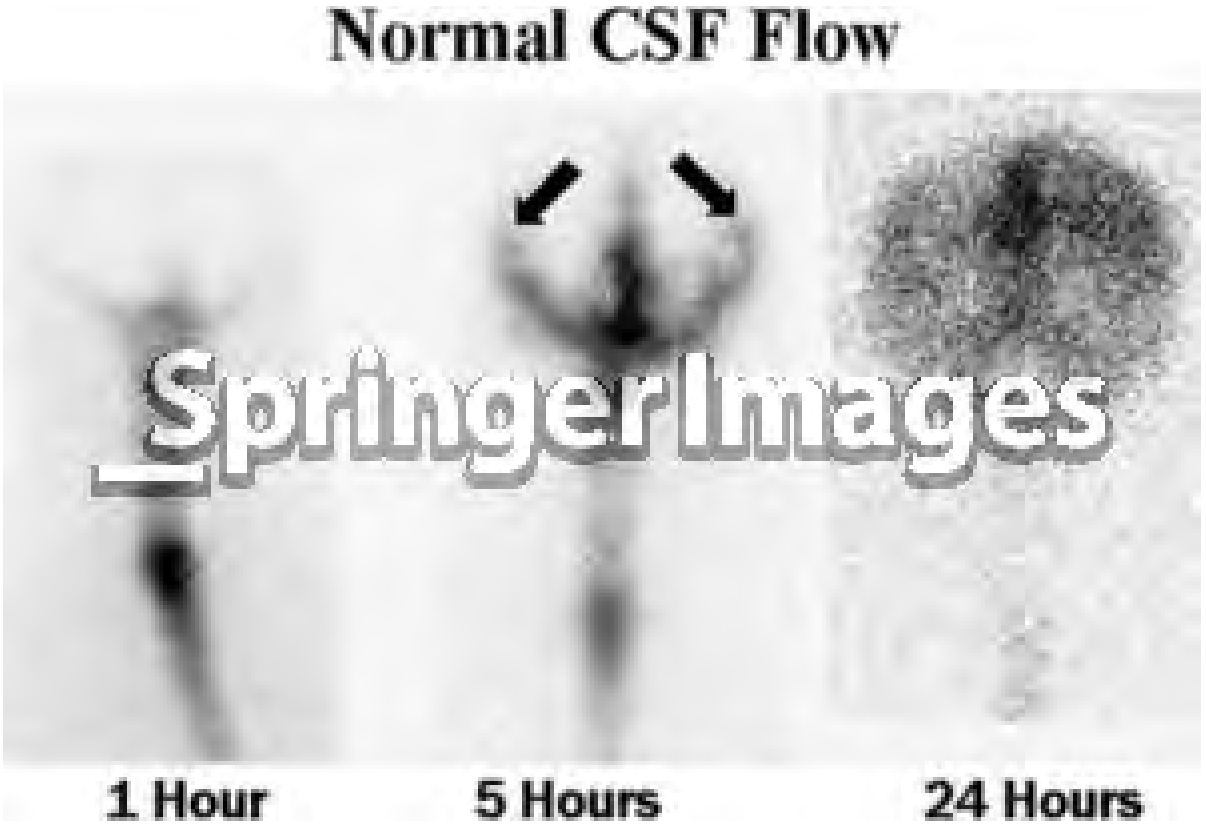
- Allows for functional (and structural) assessment of the neural axis
  - Nuclear medicine bone scan
    - Assists in the assessment of osseous infection, neoplasia, trauma
      - IV administration of radiopharmaceutical (i.e. Tc-99m-MDP), imaging of the area of interest (vs entire skeleton) can allow for the detection of abnormal bone turnover (etiology of which depends on the underlying clinical scenario)
  - PET/CT
    - Allows for assessment of functional assessment of brain parenchyma

Normal cerebral blood flow



Serial, timed blood flow images of the brain (AP projection)

Normal radionuclide cisternogram



Normal nuclear medicine bone scan

Anterior projection

Posterior projection

Summary

- Please correlate this lecture with your additional neurology-based medicine, pathology, and pharmacology lectures
- Plan to utilize this ‘Neuroimaging Overview’ lecture in correlation with your ‘Neuroimaging Imaging PI session’ preparatory reading (for optimal performance during your neuroimaging PI session).