The Basics of Neuroimaging: Techniques, Basic Anatomy and Pathology

William Pleming

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THE BASICS OF NEUROIMAGING

Techniques, Basic Anatomy and Pathology

William Pleming
RAD-AID
Structure

1. X-rays
2. Computerised Tomography
3. Magnetic Imaging
4. Angiography
5. Pathology
X-rays - attenuation

The greater the tissue density, the more the X-rays are attenuated so the fewer reach the film to expose it and turn it black.
X-rays – radiographic density

<table>
<thead>
<tr>
<th>Material</th>
<th>Color</th>
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</thead>
<tbody>
<tr>
<td>Air</td>
<td>Black</td>
</tr>
<tr>
<td>Fat</td>
<td>Dark Grey</td>
</tr>
<tr>
<td>Muscle</td>
<td>Grey</td>
</tr>
<tr>
<td>Bone</td>
<td>Light Grey</td>
</tr>
<tr>
<td>Metal</td>
<td>White</td>
</tr>
</tbody>
</table>

Lateral view of cervical spine
Where do X-rays excel?

- Rapid and preliminary assessment of bone pathology
- Rapid and preliminary assessment of chest pathology
- Post-operative assessment of surgical hardware
X-rays - role

Trauma - fractures
Arthritis
Metastases
Osteoporosis
Position of hardware
Foreign bodies
Lung abnormality
X-rays

**ADVANTAGES**
- Fast
- Cheap
- Readily available
- Good bone detail
- Dynamic images

**DISADVANTAGES**
- 2-D
- Poor soft tissue detail
- Ionising radiation (X-Ray dose)
Ionising radiation

• Absorption of X-ray radiation energy in tissues causes damage
• Critical molecules are proteins (eg enzymes) and nucleic acid (mainly DNA)
• 2 categories of effect
  – SOMATIC
  – GENETIC (HEREDITARY)
• SOMATIC EFFECTS
  – Occur in individual exposed to X-rays
  – Eg. Cataracts, leukaemias, solid tumours

• GENETIC EFFECTS
  – Occur in descendants of the individual exposed to X-rays as a result of lesions in the germinal cells eg. congenital defects
Computerised Tomography
64-slice and 128-slice CT scanners
CT - technique

- X-ray tube and detectors helically circle around body repeatedly
- Stack of axial images of varying thickness
CT - technique

Digital map of tissue density measured in Hounsfield Units and converted into grey scale
<table>
<thead>
<tr>
<th>Tissue</th>
<th>Value</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>-1000</td>
<td>very black</td>
</tr>
<tr>
<td>Fat</td>
<td>-100</td>
<td>black</td>
</tr>
<tr>
<td>Water</td>
<td>0</td>
<td>dark grey</td>
</tr>
<tr>
<td>Brain</td>
<td>+40</td>
<td>grey</td>
</tr>
<tr>
<td>Blood</td>
<td>+90</td>
<td>white</td>
</tr>
<tr>
<td>Contrast</td>
<td>+100</td>
<td>white</td>
</tr>
<tr>
<td>Bone</td>
<td>+1000</td>
<td>very white</td>
</tr>
</tbody>
</table>
CT Role

- Central role in management of accidents and emergencies
  - Trauma – cranial, visceral and bone injury
  - Stroke – hyperacute and acute stroke assessment and haemorrhage
  - Severe headache – subarachnoid haemorrhage, meningitis
  - Unconscious patient
• CT guided interventional and minimally invasive procedures
  – Diagnostic procedures
    • Eg. Biopsy
  – Therapeutic procedures
    • Eg. Vertebroplasty
Normal Anatomy
Normal Anatomy
Normal Anatomy
CT - 2 D reformats

Coronal

Sagittal
CT – intravenous contrast

- Iodine-based injection
- May cause hot flush sensation, odd taste in mouth
- Appears white (very hyperdense) on CT – “enhancement”
• Pathology $\rightarrow$ abnormal leaky blood-brain barrier $\Rightarrow$ pathology will enhance

• Normal enhancement seen in some areas – vessels, pituitary, choroid plexus
  – Why? – because at these sites, a blood-brain barrier does not exist
Risks

- Allergic reactions
- Less common with newer non-ionic compounds

INCIDENCE OF GRADE 3 ALLERGIC REACTION ie. ANAPHYLAXIS 0.02 – 0.04%
CT - intravenous contrast
CT - angiography
CT

ADVANTAGES

• Excellent bone detail
• Good for blood + Ca +
• Good soft tissue detail
• Quiet and spacious
• CT guided biopsy
• 3-D reconstructions

DISADVANTAGES

• Ionising radiation dose
• Soft tissue resolution limited
• Cost
• Use of contrast
Vascular - infarction
Vascular - infarction

Acute

Chronic
Vascular - subarachnoid haemorrhage

Grade 4 SAH with hydrocephalus
Vascular – intraparenchymal haemorrhage
Effects of intracranial masses

- Intracranial masses enlarge at the expense of normal structures
- Displacement or herniation of brain parenchyma from its normal position
- Mass effect and herniation
  - Subfalcial (subfalcine)
  - Uncal/parahippocampal
  - Transtentorial – ascending or descending
• **Tonsillar descent**
  – Inferior protrusion of cerebellar tonsils through the foramen magnum

• **Effacement of basal cisterns** (CSF spaces at base of brain eg. suprasellar cistern, perimesencephalic cistern, quadrigeminal plate cistern)

• **Hydrocephalus** – communicating or non-communicating
Mass effect and herniation

- Uncal/transtentorial
- Tonsillar
- Subfacial
Mass effect and herniation

Trauma

Tumour
Hydrocephalus - ependymoma
Trauma - extra-axial haematomas
Extradural haematoma

- Coup
- Do not cross sutures
- Can cross tentorium
- Usually lens-shaped (lenticular)
- Often underlying fracture
- May see contralateral subdural
Extradural haematoma

Pterional

Posterior fossa
Subdural haematoma

- Contracoup
- Crescentric and thin
- Can cross sutures except sagittal
- Do not cross tentorium
Acute <1 week: Hyperdense
Subacute 1-3 weeks: Isodense
Chronic >3 weeks: Hypodense
Magnetic Resonance Imaging
MRI - technique

- Protons line up in strong magnetic field
- RF pulsed in energises protons
- RF pulse turned off
- Protons ‘relax’ emitting RF signal
- 3D map of signal intensity $\rightarrow$ k-space
- Different RF pulses give different sequence
- Displayed as grey scale images in any plane
MRI – multiple planes

Axial

Sagittal

Coronal
MRI – multiple sequences

T1W

T2W
MRI – contrast

T1W

T1W + Gadolinium
Functional MRI

• Newer technology now utilised in clinical radiology
  – Diffusion-weighted imaging and fibre tracking
  – MR spectroscopy
  – Dynamic contrast-enhanced perfusion MRI
MRA - angiography

MRA Circle of Willis

MRA neck vessels
**MRI**

**ADVANTAGES**
- Does not utilise ionising radiation
- Exquisite anatomy
- Excellent soft tissue detail
- Inherent multiplanar acquisition

**DISADVANTAGES**
- Very slow
- Very expensive
- Claustrophobic + noisy
- Poor bone detail
- Availability
- Contraindications
  - Metal implants and foreign bodies, pacemakers
MRI role in neurosciences

- Subtle or small cerebral pathology
  - Infective, inflammatory, neoplastic, vascular, developmental
- Surgical planning and follow-up
- Radiotherapy planning and follow-up
- Non-accidental injury
- Post-mortem imaging and virtopsy
Vascular - arteriovenous malformation
Tumour - craniopharyngioma
Inflammatory - multiple sclerosis
Digital Subtraction Angiography
DSA - technique
DSA - technique

Femoral artery puncture

Selective catheterisation
DSA - complications

- Contrast reaction
- Puncture site: dissection, haematoma, pseudo-aneurysm, arterio-venous fistula, thrombosis and distal embolism
- Catheter-related: dissection, thrombosis, embolism, vasospasm, haemorrhage
DSA – role

- Assessment of vascular inflammatory disease where CT angiography is inconclusive (may avoid open brain biopsy)
- Endovascular therapeutic procedures
  - Aneurysm coiling
  - Arteriovenous malformation embolisation
  - Internal carotid artery stents
  - Intra-arterial thrombolysis management in acute stroke
Common carotid artery angiogram
Left internal carotid artery angiogram
SUMMARY

• Neuroimaging is central to diagnostic and therapeutic patient management
• Awareness of some of the imaging modalities available, advantages, limitations and potential risks
• Awareness of neuroanatomy
• Awareness of neuropathology
Thank you