neuroimaging [created by Paul Young 27/11/07]

head trauma

- CT is the primary modality for the initial evaluation of patients with head injury
- although MRI is more sensitive in detecting intracranial traumatic lesions, it is limited by a longer examination time, less conspicuity of hyperacute haematomas & difficulty in monitoring patients. MRI can identify small foci of old haemorrhage and gliosis and can evaluate the presence and extent of diffuse axonal injury (shear injury) with greater sensitivity than CT

neoplasm

- On CT, low grade gliomas may appear as subtle non enhancing masses while higher grade gliomas often demonstrate heterogenous enhancement with large areas of necrosis & vasogenic oedema
- On CT, metastatic lesions may be low density and enhancing masses as seen with breast or lung carcinoma or they be high density with haemorrhagic components as seen with renal cell carcinoma, melanoma & thyroid tumours
- MRI has high sensitivity but low specificity in evaluation of neoplasms

parenchymal infection

- parenchymal infections include encephalitis, cerebritis & abscess

(i) encephalitis:
- MRI is more sensitive than CT for encephalitis & demonstrates the changes earlier
- On MRI, affected brain typically hypodense on T1-weighted images & hyperintense on T2-weighted images
- In herpes simplex encephalitis imaging studies show gyral oedema with a predilection for the temporal lobes

(ii)cerebritis & cerebral abscess
- an early phase of abscess formation that looks like encephalitis but is more focal in nature
- cerebral abscess produces a localised collection of pus surrounded by a fibrous capsule
- on CT, an abscess cavity demonstrates central hypodensity, a thin isodense wall & surrounding low density oedema. Following contrast administration, there is enhancement of the capsule

(iii) extraaxial collections
- include ventriculitis, meningitis, subdural and extradural empyema
- MRI is generally the modality of choice and in general with both CT & MRI contrast is required

vascular lesions

- although CT only demonstrates about half of infarct within the first 48 hours, it remains the imaging modality of choice in evaluating patients with symptoms of TIA, RIND or completed stroke

- in the acute setting, CT can identify the location and extent of infarction; distinguish among ischaemic stroke, primary intracerebral haemorrhage & effectively exclude mimics
- hypertensive encephalopathy is a syndrome that occurs in patients with elevated blood pressure of any cause. It causes hyperintensity of white matter at the grey-white junction on T2-weighted images. Cortical and subcortical white matter changes occur primarily in the occipital lobes
- hypotensive encephalopathy can occur in patients who have suffered a severe hypotensive episode or cardiac arrest. It is characterised by infarction in a watershed distribution
- venous infarction can occur in isolation and is associated with thrombosis of a dural sinus or large draining vein. Venous infarction is typically haemorrhagic and primarily affects the white matter

- subarachnoid haemorrhage is evaluated by non contrast CT imaging.
- if the CT is positive and the patient is a surgical candidate an angiogram is performed to identify aneurysms or AVMs
- for patients with suspected vasospasm, xenon CT and transcranial doppler have proved useful

- vascular malformations inlcude AVMs, capillary telangiectasia, cavernous angioma & venous angiomas. They may not be visible on plain CT.

brain imaging patterns of disease

oedema:
- cerebral oedema is caused by localised or diffuse abnormal accumulation of water and sodium. This differs from cerebral engorgement caused by vasodilation or obstructed venous outflow
- three types of oedema have been described:

(i) vasogenic oedema:
- is the result of increased capillary permeability and involves mainly white matter
- most often associated with tumour, abscess or trauma but can also been seen with infarct and ischaemia

(ii) cytotoxic oedema:
- is the result of cellular swelling and involves both grey and white matter.
- ischaemia, anoxia and hypoosmolar states are the most common causes

(iii) interstitial oedema:
- is the result of cerebrospinal fluid into the periventricular white matter
- this form of oedema is secondary to conditions that impede CSF absorption
- except for location, the CT and MRI appearance of all types of oedema is similar

haemorrhage:
- intracranial haemorrhage may be parenchymal or extraaxial (epidural, subdural or subarachnoid)
- parenchymal haemorrhage can be traumatic in origin but is more likely non-traumatic from underlying disease such as hypertension, neoplasia or vascular anomaly
- extradural and subdural haematoma are most likely the result of trauma
- subarachnoid haemorrhage is most often traumatic but may be associated with ruptured aneurysm
- the imaging appearance of haemorrhage is dependent on the age of the haemorrhagic event.
- On CT, acute haemorrhage typically appears as hyperdense; however they may appear as isodense in anaemic patients or in patients with coagulopathy who fails to produce clot retraction. As clot retracts the density may rise for 2 to 3 days after the initial event. The CT appearance then gradually reduces in density progressing through an isodense stage at 1-6 weeks depending on the size and finally a hypodense stage
- MRI appearances of haemorrhage are more complicated because of the varying paramagnetic properties of blood breakdown products

mass effect & herniation:

(i) subfalcine herniation
- occurs when the medial surface of a hemisphere is compressed against or displaced beneath the falx
- early signs may appear as compression or distortion of the lateral ventricles
- later stages are recognised by deviation of the falx & identification of midline structures that are crossing the midline

(ii) transtentorial herniation
- occurs when a mass arising on either side of the tentorium results in brain herniation through the tentorium results in brain herniation through the tentorial incisura
- descending transtentorial herniation is caused by a supratentorial mass that displaces the medial temporal lobe throught the incisura. On CT the herniated brain pushes against and rotates the brainstem producing widening of the ipsilateral brainstem cistern and effacement of the contralateral cistern
- ascending transtentorial herniation is caused by an infratentorial mass that displaces the pons, vermis & adjacent portions of the cerebellar hemispheres upward throught the incisura. On CT, the brainstem cisterns are symmetricallyeffaced as the cerebellar vermis bulges up through the incisura

(iii) tonsillar herniation
- occurs when the cerebellar tonsils are pushed through the foramen magnum

CT

general:
- the most widely used imaging modality for evaluation of critically ill patients with CNS pathology. It is widely available, rapid & accurate and has virtually no contraindications in the acute setting
- the clinical utility may be increased by multiple methods including contrast enhancement, window techniques and various reconstructions
- with contrast agents, lesions that cause a breakdown of the blood brain barrier as well as normal or abnormal vascular structures 'light up'
- spiral or helical CT allows rapid imaging through a large volume of the body usually with a single breath-hold. Rapid, thin-section axial images can be obtained with very little artefact & they can be merged and reproduced in any plane
- xenon CT involves the inhalation of xenon gas over a period of time with sequential cuts and subsequent calculations of xenon uptake. This technique is valuable for measuring cerebral blood flow

advantages of CT:
(i) useful for diagnosis of CNS trauma, SAH, ICH, haemorrhagic and ischaemic stroke, hydrocephalus, cerebral oedema and the presence of space occupying lesions
(ii) lower cost than MRI
(iii) readily available with short examination time
(iv) safe in the presence of pacemakers, surgical clips & ferromagnetic substances

disadvantages of CT:
(i) the need to transfer the patient to a site where resuscitation & monitoring facilities are limited
(ii)) the need to sedate and possibly intubate patients who are agitated
(iii) low sensitivity in acute stroke
(iv) low sensivity for detecting brainstem lesions
(v) potential need for iv contrast with risk of anaphylaxis and renal failure

CT imaging in TBI

Category	Definition
Diffuse injury (DI) I	No visible intracranial pathology seen on CT scan
DI II (diffuse injury)	Cisterns are present with midline shift 0–5 mm and/or Lesion densities present No high or mixed density >25 mm May include bony fragments and foreign bodies
DI III (swelling)	Cisterns are compressed or absent with midline shift 0–5 mm NO high or mixed density >25 mm
DI IV (shift)	Midline shift >5 mm NO high or mixed density >25 mm
Evacuated mass lesion	Any lesion surgically evacuated
Non-evacuated mass lesion	High or mixed density lesion >25 mm, not surgically evacuated

MRI

General:
- uses magnetic field gradients and radiofrequency pulses rather than ionising radiation
- many sequences that vary the MRI signal parameters are obtained allowing tissue characterisation based on the tissue's inherent response to magnetic field and radiofrequency pulses
- a gadolinium-based contast agent can be injected intravenously which allows better visualisation of intracranial and intraspinal pathology
- diffusion weighted MRI is based on the evaluation of free versus restricted movement of water molecules. Diffusion weighted MRI is now considered the standard sequence in evaluation of acute stroke because it is more sensitive than standard MRI for identification of acute stroke and for differentiating stroke for other pathologies

Disadvantages of MRI:
- MRI is contraindicated in patients with:
(i) pacemakers
(ii) certain cardiac valves
(iii) intraocular metal fragments
- careful screening is required for the presence of cerebral aneurysm clips & other metallic devices, stents and surgical implants
- respirators and physiological monitors must be MRI compatible & only oxygen cylinders composed of aluminium may enter the scanner
- delays result from all of the above precautions and modifications
- basic medical instruments such as stethoscopes, haemostats, & scissors must remain outside the scanner

Advantages of MRI:
(i) provide superior contrast and resolution of grey & white matter compared with CT facilitating easy identification of deep structures within the brain & visualisation of the brainstem & posterior fossa
(ii) use of non-ionising energy

other modalities

angiography:
- percutaneous transfemoral catheterisation is used to evaluate cerebral and spinal vascular anatomy and integrity.
- cerebral angiography is an invasive procedure & imposes some risks. The overall complicationrate is 2-4% with most complications being minor and transient such as groin haematoma,infections and minor allergic reactions. More severe complications such as cerebral infarction,seizure and death occur infrequently
- cerebral angiography remains the gold standard for establishing the presence of cerebral aneurys, or vascular malformations
- interventional neuroradiology techniques include embolisation of vascular tumours, aneurysms,and AV malformations; stent placement; angioplasty and thrombolysis

nuclear medicine studies:
- evaluation of CNS pathology with nuclear medicine techniques is still undergoing investigation.
- the major use for this technique is in demonstrating absence of cerebral blood flow in patients in whom clinical brain death testing and cerebral angiography are precluded