Regional Cerebral Blood Flow (rCBF) Examination

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^{133}Xe rCBF

- inhaled / injected ^{133}Xe - oldest & least expensive technique!

- precise measurements of ***cortical*** blood flow (provides no information about ***subcortical*** perfusion).
- can be used at bedside, in operating room, or in ICU.
- commonly used with *hypercapnia* or *hypotension* to test autoregulatory capacity of resistance vessels (e.g. focal failure of vasodilatory response, if distributed in territory of major vessel = evidence of maximal dilatation and, therefore, reduced perfusion pressure).

Stable Xe-CT

- CT tracks changes in tissue density over period of ≈ 6 minutes when inhaled nonradioactive (stable) 28% Xenon gas circulates over capillary bed.
  - Xenon has anatomic number close to iodine (therefore attenuates X-ray beam in similar fashion).
  - unlike iodine, Xenon is freely diffusable and penetrates BBB.
- *Xenon distribution* in brain depends on regional blood flow - ***change of Hounsfield numbers*** (over time during Xenon inhalation) is displayed as colour maps.
- provides automatic registration to anatomic information in baseline CT scan.
- *Xenon washout* occurs relatively rapidly (allowing repeat examination after 15–20 min).
- disadvantages:
  1) physiologic & *anesthetic effects* of high xenon concentrations (≈ 30%).
  2) any patient movement during 6-min period causes misregistration of data.
  3) Xenon uptake may be impaired in severe pulmonary disease.

Perfusion CT (pCT)

see p. D64 >>

- CT tracks transient density changes in blood vessels and brain parenchyma during first pass passage of IV bolus of contrast medium (passage of contrast-medium bolus causes ***transient increase in Hounsfield units***, proportional to iodine concentration in perfused tissue) → maps of cerebral blood volume (CBV), mean transit time (MTT), and cerebral blood flow (CBF) can be obtained.

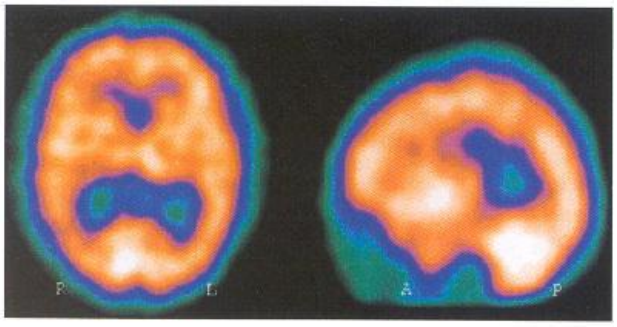
- CBF measurement is systematically lower compared to Xe-CT.

Single-Photon Emission Computerized Tomography (SPECT)

- tomographic imaging of **injected radioisotopes**:
  1) ^{133} Xe
  2) ^{123} I isopropyl iodoamphetamine (IMP)
  3) ^{99m} Tc ethyl cysteinate dimer (ECD)
  4) ^{99m} Tc hexamethylpropylene amine oxide (HMPAO)

- physical-mathematical principles similar to CT, but source of radiation is internal to imaged organ.
- isotopes emit γ-radiation as ***single photons*** (vs. PET – positrons) - more favorable cost/benefit ratio than PET (i.e. less expensive and less sophisticated imaging technology than PET).
- images can be displayed in ***axial***, ***coronal***, or ***sagittal*** projections.
- spatial resolution is inferior to CT and MRI.
- used widely for imaging of CEREBRAL PERFUSION (CBF) (e.g. with ^{123}I-IMP).
- CEREBRAL BLOOD VOLUME (CBV) imaging is also available (e.g. with ^{99m}Tc-labeled RBCs); combined flow/volume scans are possible.
- SPECT of *ischemia-infarction* - high sensitivity and early detection (specificity is not yet established):
  artery stenosis → perfusion pressure↓ → CBF↓ + autoregulatory CBV↑ (i.e. CBV/CBF ↑).
  infarction → metabolic demand↓ → CBF↓ + CBV↓
- in contrast to PET, SPECT allows scanning hours after injection of tracer - allows cerebral blood flow imaging under unique circumstances (e.g. during epileptic seizure).
- another promising use - **determinations of cerebrovascular reserve** through *DILATORY CHALLENGE* (CO_2 or acetazolamide*). *Diamox SPECT
  e.g. perfusion may be normal at rest but show impairment following challenge with acetazolamide (normally cerebral flow increases following acetazolamide administration).

Normal ^{99m} Tc HMPAO SPECT of brain:



Functional MRI (fMRI)

- evaluates CBF by looking at difference between venous OXYHEMOGLOBIN and DEOXYHEMOGLOBIN - blood oxygen level–dependent (BOLD) contrast technique.

DEOXYHEMOGLOBIN is **paramagnetic** - detected as ↓ T2 signal.
OXYHEMOGLOBIN is **diamagnetic** - little effect on T2 signal.

- during cortical activation, rCBF to eloquent cortex increases, but oxygen extraction changes little (t.y. deguonies patiekiama daugiau negu padidėja jo poreikis) → relative increased concentration of OXYHEMOGLOBIN and relatively decreased concentration of DEOXYHEMOGLOBIN draining activated cortex → decrease of lowered signal intensity, i.e. signal increase in activated cortex (relative to contiguous cortex) – this is seen via subtracting one data set from other (one obtained with, other without stimulus).

N.B. BOLD effect is observed at draining venous bed (vs. capillaries) level – there is always ***some shift***; e.g. motor cortex drains posteriorly and motor tasks may show activation regions over sensory cortex!

- use various paradigms (motor tasks, speech, sensory stimulation)
  N.B. always use speech – to determine which hemisphere is dominant.
- biggest fear – vessels around tumor are maximally dilated and won't show BOLD effect (surgeon may falsely assume that it is not eloquent cortex); H: start with breath-holding test – CO_2 increases blood flow 4-5% (vs. tasks – only 2-3%) – look if area of interest shows BOLD effect – if not then of course may not excpect activation with paradigm task.
- fMRI has been used (± along with DTI) to ***map cortical areas*** (language, motor function, interictal spikes, partial seizure foci*, etc) – resolution better than PET!
  *difficult, because seizures are *unpredictable* and associated with *movement* (obscures fMRI image).

RESTING STATE fMRI (RS-fMRI)

- connects areas of brain where BOLD signal fluctuates in synchrony.
- especially good for noncooperative patients (e.g. kids).
- does not work well if brain has malformations with disorganized networks (e.g. tuberous sclerosis).
- light sedation (with any agent) is OK but not general anesthesia.

Positron emission tomography (PET)

- since *CBF is tightly coupled to brain metabolism*, local uptake of **2-deoxyglucose*** is also good index of rCBF.
  *labeled with positron emitter (such as ^{18}F, ^{11}O, and ^{15}O)

CEREBROVASCULAR RESERVE & REACTIVITY

- response of CBF to vasodilator challenge with 1000 mg of IV ACETAZOLAMIDE:

Type I: normal baseline CBF with 30-60% increase following ACZ challenge

Type II: decreased baseline CBF with blunted response of < 10% increase (or < 10 mL/100 g/min absolute increase) after ACZ challenge

Type III: decreased baseline CBF with paradoxical decrease of regional CBF following ACZ challenge - suggesting steal phenomenon in regions with maximally dilated vasculature at baseline

BIBLIOGRAPHY for ch. "Neurovascular Examination" → follow this LINK >>