Regional Cerebral Blood Flow (rCBF) Examination

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133Xe rCBF

- inhaled / injected 133Xe - 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 diffusible 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)

- 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) $^{133}\text{Xe}$
  2) $^{123}\text{I}$ isopropyl iodoamphetamine (IMP)
  3) $^{99m}\text{Tc}$ ethyl cysteinate dimer (ECD)
  4) $^{99m}\text{Tc}$ hexamethylpropylene amine oxide (HMPAO)

- Physical-mathematical principles similar to CT, but source of radiation is internal to imaged organ.
- Isotopes emit $\gamma$-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 $^{99m}\text{Tc}$-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 $^{99m}\text{Tc}$ HMPAO SPECT of brain:

![SPECT Images](image)

Functional MRI (fMRI)

- Evaluates CBF by looking at difference between venous oxyhemoglobin and deoxyhemoglobin - blood oxygen level–dependent (BOLD) contrast technique.

<table>
<thead>
<tr>
<th>Deoxyhemoglobin</th>
<th>Paramagnetic - detected as ↓ T2 signal.</th>
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<tr>
<td>Oxyhemoglobin</td>
<td>Diamagnetic - little effect on T2 signal.</td>
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- During cortical activation, rCBF to eloquent cortex increases, but oxygen extraction changes little (t.y. degunonies patiekina 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 – CO₂ 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 expect 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 (obscurrs 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 ¹⁸F, ¹¹O, and ¹⁵O)

**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 >>