

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 atomic 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 ($\approx 30\%$).
 - 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) \rightarrow maps of cerebral blood volume (CBV), mean transit time (MTT), and cerebral blood flow (CBF) can be obtained.

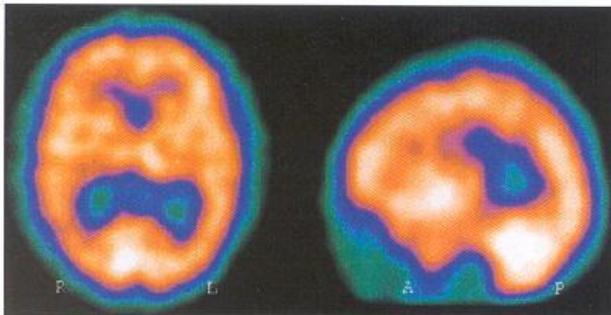
- CBF measurement is systematically lower compared to Xe-CT.

Single-Photon Emission Computerized Tomography (SPECT)

- tomographic imaging of **injected radioisotopes**:

- 1) ^{133}Xe
 - 2) ^{123}I isopropyl iodoamphetamine (IMP)
 - 3) $^{99\text{m}}\text{Tc}$ ethyl cysteinate dimer (ECD)
 - 4) $^{99\text{m}}\text{Tc}$ 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 $^{99\text{m}}\text{Tc}$ -labeled RBCs); combined flow/volume scans are possible.
 - SPECT of **ischemia-infarction** - high sensitivity and early detection (specificity is not yet established):
 - artery stenosis** \rightarrow perfusion pressure \downarrow \rightarrow CBF \downarrow + autoregulatory CBV \uparrow (i.e. CBV/CBF \uparrow).
 - infarction** \rightarrow metabolic demand \downarrow \rightarrow CBF \downarrow + CBV \downarrow
 - 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 $^{99\text{m}}\text{Tc}$ 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 \downarrow 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 patiekiamą daugiau negu padidėja jo poreikis) \rightarrow relative increased concentration of **OXYHEMOGLOBIN** and relatively decreased concentration of **DEOXYHEMOGLOBIN** draining activated cortex \rightarrow 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* (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 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 >>](#)