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IV-5. An Original Method for the Concomitant Tomographic Assessment of Cerebral Blood Flow, Oxygen Extraction Rate, Blood Volume, and Exchangeable Water Volume in Man

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One of the most cumbersome features of the methods using externally detected radioactive indicators in view to determine cerebral blood flow and other cerebral kinetic parameters is the unavoidable introduction into the equations of a parameter characterizing the tissular distribution - tissue-to-blood partition coefficient or distribution volume - of the indicator. Disregarding this distribution factor may nonetheless lead to unaccurateness in the applied computing methods.

The present investigation combines the potentials of dynamic positron emission tomography (PET) for the quantitation of detection data (1-4) and the use of indicators with physiological interest in view to noninvasively evaluate local cerebral blood flow (F_i) and oxygen extraction rate (E_iO_2) and to simultaneously determine local cerebral erythrocytic blood volume (V_iO_2) and volume of exchangeable water (V_iH_2O).

The subject is allowed to successively inhale a single breath of $C^{15}O_2$ and of $^{15}O_2$. The local cerebral concentrations of the indicators are measured by a sequence of 1 minute lasting PET scans, during 8 minutes from time zero of inhalation(°) The arterial blood concentrations are determined on samples withdrawn through a humeral catheter.

Preliminary studies (5) using $C^{15}O_2$ and sequential PET have shown that initial variation in the effective volume of distribution of $H^{15}O_2$ within the cerebral tissue leadsto propagated errors, if classical numerical methods are utilized for solving the differential equation of the model.

Computation of local cerebral blood flow F_i and local cerebral volume of exchangeable water V_iH_2O is based on following equation :

$$C_{bi}(t) = F_iC_a(t) * e^{-(F_i/V_iH_2O + \lambda)t} + \varepsilon_i(t)$$

with $C_{bi}(t)$, the tissular concentration of the tracer ; $C_a(t)$, the arterial concentration of the tracer ; λ, the physical decay constant of ^{15}O and $\varepsilon_i(t)$, the error resulting from the initial variation in the effective distribution volume of radiowater.

We demonstrated that $\varepsilon_i(t)$ vanishes for $t > 1$ min. Values of F_i and V_iH_2O are evaluated by linearization of the equation and iterative processing of partially time-integrated cerebral data $C_{bi}(t)$ (seven 1min intervals from t= 1 min to t= 8 min).

Determinations of local cerebral oxygen extraction rate E_iO_2 and local cerebral erythrocytic blood volume V_iO_2 are based on the following set of equations, giving the respective concentrations of

(°) ECAT II (E&G Ortec)

radiooxygen (C_{bi}^{ox}), of locally produced radiowater (C_{bi}^{lw}) and of re-circulating radiowater (C_{bi}^{rw}) within cerebral tissue :

$$C_{bi}^{ox}(t) = F_i(1 - E_{iO2})\, C_a^{ox}(t) * e^{-(F_i/V_{iO2} + \lambda)t} + \varepsilon_i^{ox}(t)$$

$$C_{bi}^{lw}(t) = F_i E_{iO2}\, C_a^{ox}(t) * e^{-(F_i/V_{iH2O} + \lambda)t} + \varepsilon_i^{lw}(t)$$

$$C_{bi}^{rw}(t) = F_i C_a^{w}(t) * e^{-(F_i/V_{iH2O} + \lambda)t} + \varepsilon_i^{rw}(t)$$

with C_a^{ox}, the arterial concentration in radiooxygen; C_a^{w}, the arterial concentration in radiowater and ε, the respective errors resulting from the variations in distribution volumes of the indicators, vanishing as hereabove for t>1 min. E_{iO2} and V_{iO2} are computed, using an iterative processing on data collected from t = 1min to t = 8min.

The table shows normal values obtained from 5 normal subjects, aged from 30 to 50 years, in mean predominantly gray and white matter (± 1 S.D.). The cerebral slice is located at 5 cm above the orbitomeatal reference plane.

	Gray matter	White matter
Cerebral blood flow cm3/min.100gr	72.7 ± 8.0	31.4 ± 6.3
Oxygen uptake rate µmol/min.100gr	236 ± 27	108 ± 14
Exchangeable water cm3/100gr	69.6 ± 5.4	59.3 ± 5.0
Erythrocytic volume cm3/100gr	2.7 ± 0.2	1.8 ± 0.2

The method was applied to the study of focal and perifocal edema in hemispheric cerebral infarcts ; the size and importance of the edema was correlated with the prognosis of the cerebral ischemia.

1. Raichle ME, Markham J, Larson K, Grúbb RL, Welch MJ. J Cereb Blood Flow Metab 1981;1(suppl 1):19-20.
2. Huang SC, Phelps M, Carson R, Hoffmann E, Plummer D, Mac Donald N, Kuhl D. J Cereb Blood Flow Metab 1981;1(suppl 1):31-32.
3. Raichle ME, Larson KB, Markham J, Depresseux JC, Grubb RL, Ter-Pogossian MM. J Cereb Blood Flow Metab 1981;1(suppl 1):7-8.
4. Huang SC, Carson R, Phelps ME. J Cereb Blood Flow Metab 1982;2: 99-108.
5. Depresseux JC. In: Heiss WD, Phelps ME, eds, Positron emission tomography of the brain. Berlin: Springer Verlag, 1983,in press