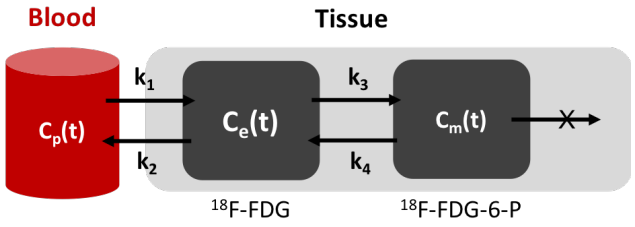
Biomedical Imaging

Exercise NUC #2 – Quantitative PET Data Analysis

The purpose of the exercise is to implement and study kinetic modeling and data fitting for quantitative PET data analysis of ^{18}F-FDG tracer experiments.

Task 2.1

Upon injection, ^{18}F-FDG is taken up by tissue via glucose transporter and converted to ^{18}F-FDG-6-phosphate (^{18}F-FDG-6-P) as shown schematically in the figure below. For the analysis of rate constants (k_2, k_3, k_4) we consider the two tissue compartments (c_e, c_m) and treat the blood/plasma compartment (c_p) separately, i.e. we solve the equations for an ideal delta input function (impulse response) and convolve the results with the actual input signals.



- Derive and write down the differential equations for the concentrations of extracellular ($c_e(t)$) and metabolized ^{18}F-FDG ($c_m(t)$) ; assume that the input from the blood plasma is a delta function, i.e. $c_e(0) = k_1$ and $c_m(0) = 0$, also assume k_4=0.

Task 2.2

- Download the *.zip file for NUC_EXERCISE2 from https://moodle-app2.let.ethz.ch and unpack it on your computer.
- Learn about solving differential equations in Matlab using dsolve (type help dsolve on Matlab prompt) and implement the differential equations derived above to obtain the impulse response functions of the extracellular compartment $c_e(t)$ and the metabolized compartment $c_m(t)$.
- Now implement convolution of the impulse response functions with the blood plasma input curve $c_p(t)$.
- Inspect the tissue concentration-time curves for $c_e(t)$ and $c_m(t)$ using the following values: k_1=0.1 min^{-1}, k_2=0.3 min^{-1}, k_3=0.5 min^{-1}
- Rate constant k_4 was assumed to be zero – justify why such an assumption is valid by considering the process of ^{18}F-FDG tracer uptake and metabolization.

Task 2.3

In a real-word experiment, blood plasma concentration $c_p(t)$ is measured in a blood vessel near the tissue of interest $(c_e(t) + c_m(t))$ and both measurements are input to a fitting procedure to obtain the kinetic rate constants (k_1, k_2, k_3).

- Inspect the blood plasma concentration-time curve $c_p(t)$ as available in the code.
- Add Poisson noise to $c_p(t)$ and $c_t(t)$ by converting concentrations into photon counts such as to obtain a peak SNR of 100 of the blood plasma signal; inspect the resulting concentration-time curves.
- Implement the fit function to determine the rate constants (k_1, k_2, k_3) from noisy $c_p(t)$ and $c_t(t)$ input.
- Determine mean and standard deviation of the fitted rate constants (k_1, k_2, k_3) for multiple repetitions of adding noise and fitting the noisy data.

- Reduce the SNR by a factor 10 and repeat the experiments above; how do mean and standard deviation of fitted rate constants change? Which conclusion do you draw in terms of required signal-to-noise ratio of the input PET data?

Questions?

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