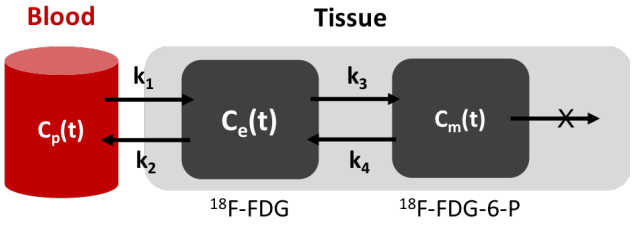
Biomedical Imaging

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 a an ideal delta input function (impulse response and convolve the results with the actual input function.



- 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.
- 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 resulting 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=0.6 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 update and metabolization.

Task 2.2

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 display.
- 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 in order to perform reliable quantitative analysis?

Questions?

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