CIBM Center for Biomedical Imaging

CIBM Annual Symposium 2022

Campus Biotech, Geneva | 30th November

ESTIMATION OF LYMPH NODE MICROSTRUCTURE FROM MONTE-CARLO SIMULATED DW-MRI SIGNALS

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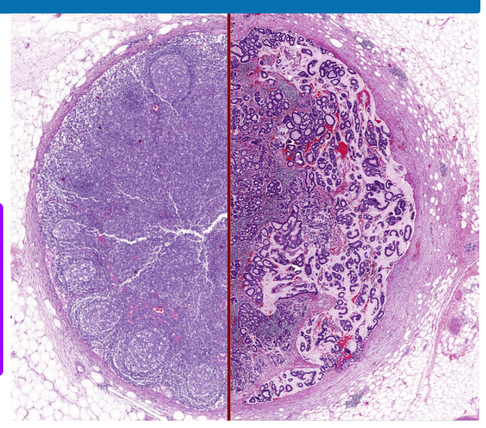
MOTIVATION

Cancer detection with biopsy:
Invasive and long-time process

Virtual biopsy
Has diffusion MRI the potential to **detect tumor non-invasively**?



Healthy lymph node (left) and tumor (right)

METHODS

CEXI: CELLULAR EXCHANGE IMAGING

CEXI is a compartmentalized model of **permeable cell tissue** assuming

- **spherical** cells in one intracellular compartment,
- **slow** water exchange between intra- and extra- compartments,
- **mixed** compartments.

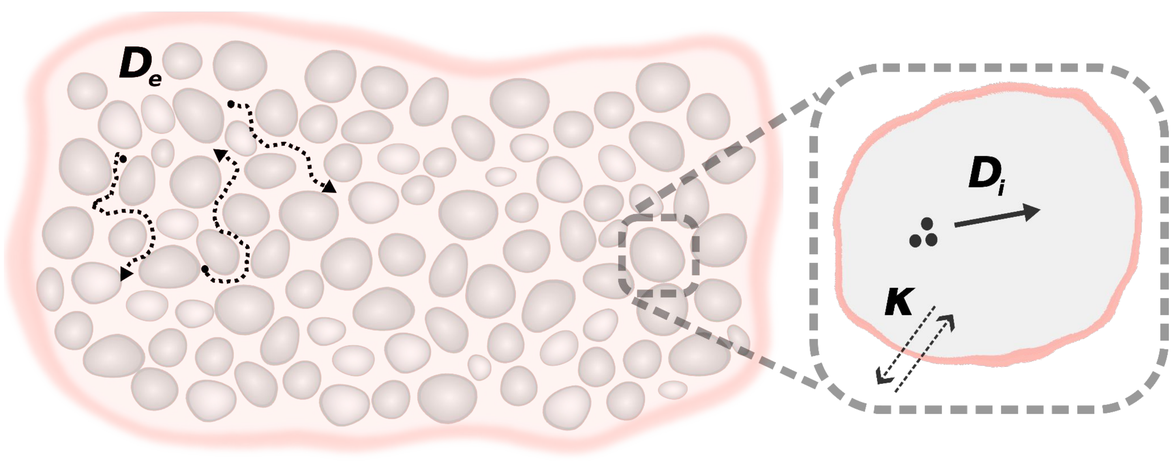


Illustration of the extracellular (left) and the intracellular (right) compartments of CEXI

$$
\begin{cases}
S_{CEXI} = f' e^{-q^2 t D'_i} + (1-f') e^{-q^2 t D'_e}, \\
D_i = D_i(R_s, \Delta, \delta), \quad \textit{(Neuman (1974))} \\
f' = \dfrac{1}{(D'_i - D'_e)} \left(f_i D_i + (1-f_i) D_e - D'_e \right), \\
\tau_{ex} = (1-f_i) \dfrac{V/A}{\kappa}, \\
D'_{i,e} = \dfrac{1}{2} \left(D_i + D_e + \dfrac{1}{q^2 D_e} \pm \left[\left[D_e - D_i + \dfrac{2f_i - 1}{q^2 \tau_{ex}} \right] + \dfrac{4 f_i (1-f_i)}{q^4 \tau_{ex}} \right]^{\frac{1}{2}} \right).
\end{cases}
$$

- f_i Volume fractions
- $D_i D_e$ Diffusion coefficients
- κ Membrane permeability
- τ_{ex} Exchange time
- R_s Cell radius

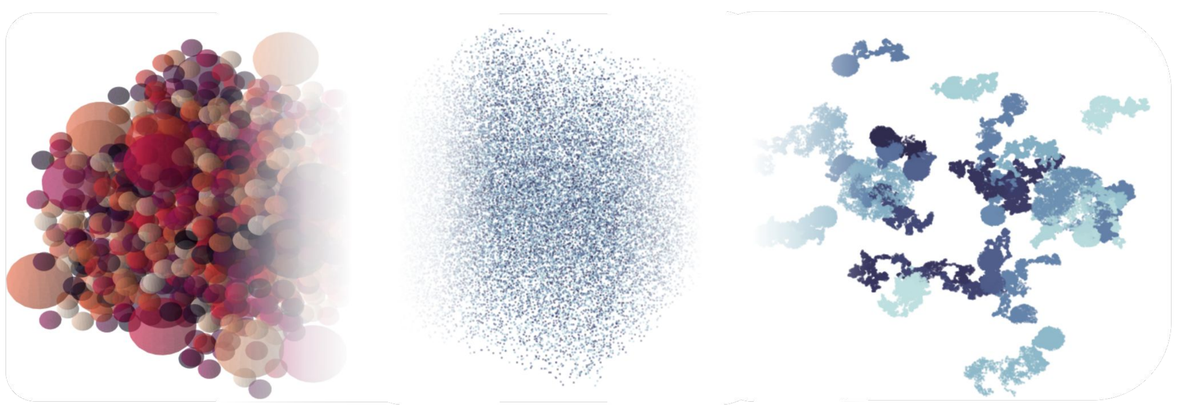
EXPERIMENTS: MONTE-CARLO SIMULATIONS

CEXI was evaluated on Monte-Carlo simulated DW-MRI signals with

- one **PGSE sequence,**
- in multiple **substrates.**

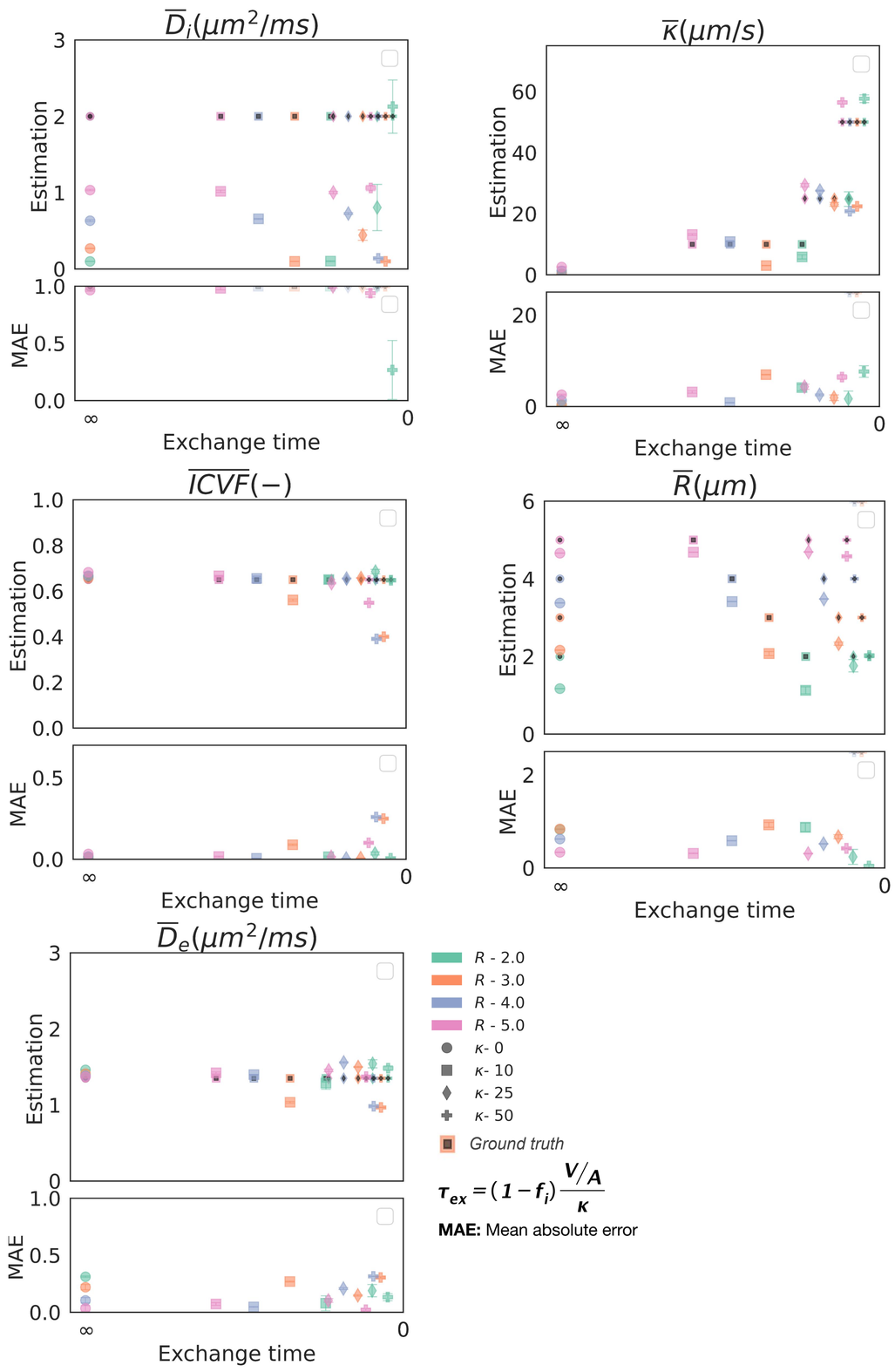
Δ(ms)	δ(ms)	TE(ms)	b(ms/μm²)
12, 20, 30, 40	4.5	50	1, 2.5, 4, 5.5, 7

R (μm)	$ICVF$	Voxel (μm)	$D_{e,i}$ (μm²/ms)	κ (μm/s)
2, 3, 4, 5	0.65	100	2	0, 10, 25, 50



Monte-Carlo simulations: Substrate (left), particles initialization (centre) and trajectories (right)

RESULTS : CEXI FITTING



$$\tau_{ex} = (1-f_i)\frac{V/A}{\kappa}$$

MAE: Mean absolute error

- **Accurate estimates at permeability $\kappa \leq 25\ \mu m/s$** for Δ in 12-40 ms.
- CEXI cannot estimate D_i.
- MAE on R_s increases in smaller cells.
- MAE on f_i, κ, D_e are independent on R_s.

CONCLUSION

- CEXI estimates f_i, κ, D_e and R_s accurately under Kärger's assumptions.
- Permeability influences the optimal PGSE sequence :
  - Small cells
  - Fast permeability
  - } Short diffusion time
  - Big cells
  - Slow permeability
  - } Long diffusion time

MC/DC
simulator

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