Estimating Pharmaco-kinetic Maps from Undersampled kt-space in MRI

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Dynamic Contrast Enhanced MRI (DCE-MRI)

- Time-resolved MRI (T1-weighted Gradient echo based)
DCE-MRI pipeline

Anatomical Images: \( S(t) \)

Contrast Agent Concentration: \( CA(t) \)

Tracer-Kinetic (TK) parameters:

- Contrast Agent relaxivity
- MRI physics \( (M0, T1) \)

TK modeling
- AIF

\( K_{\text{trans}} \)  \( V_p \)
Tracer Kinetic Models in DCE-MRI

- Tracer Kinetic modeling of contrast agent kinetics across the capillaries

\[ K_{\text{trans}} \]: Forward transfer rate coefficient

\[ K_{\text{ep}} \]: Backward transfer rate coefficient

\[ v_p \]: Plasma volume

\[ v_e \]: Extra-cellular, extra-vascular volume

\[ F_p \]: Flow
Non-linear extended Tofts model

\[ \min_{K_{trans}, K^{ep}, v_p} \| C_m(t) - C_A(t) \|^2_2 \]

\[ C_m(t) = K_{trans} \int_0^t C_p(u)e^{-K^{ep}(t-u)} du + v_p C_p(t) \]
Purpose of this work

• To develop a network that improves the computational speed of nonlinear TK modeling.
• To exploit patient specific AIFs in our network
• To demonstrate utility on high time resolution (<5s), shorter scan time (<6 min) DCE-MRI data
Methods

- Our proposed AIF-TK-NET was designed to estimate TK parameters from high temporal resolution (4.8 s), and shorter scan time (5.2 minutes) data.
Results

TK-net without AIF

$K_{ref}^{trans}(min^{-1})$

$0.0107 \pm 1.96(0.02037)$

$K_{ref}^{ep}(min^{-1})$

$0.005772 \pm 1.96(0.02827)$

$v_p (unit - less)$

$-0.009877 \pm 1.96(0.03815)$

AIF-TK-net

$K_{ref}^{trans}(min^{-1})$

$0.001667 \pm 1.96(0.01708)$

$K_{ref}^{ep}(min^{-1})$

$-0.0008839 \pm 1.96(0.0232)$

$v_p (unit - less)$

$-0.01073 \pm 1.96(0.03469)$
Conclusion

• We propose a novel AIF-TK-NET for rapid inference of TK maps in nonlinear DCE models

• Our net effectively integrates patient specific AIFs, and as a result, demonstrated superior accuracy in estimating the TK maps compared to an existing TK-net on high time resolution DCE scans.

• The proposed AIF-TK-NET is ~500x times faster than nonlinear voxel-wise fitting
Extend this work to undersampled MRI using the network to approximate the inverse of model fitting. This will allow physician to see high resolution scans of the brain, allowing for earlier diagnosis of neurological diseases.