Use Of Reference Region Model to Improve Arterial Input Function Selection for Estimating Kidney Function with DCE-MRI

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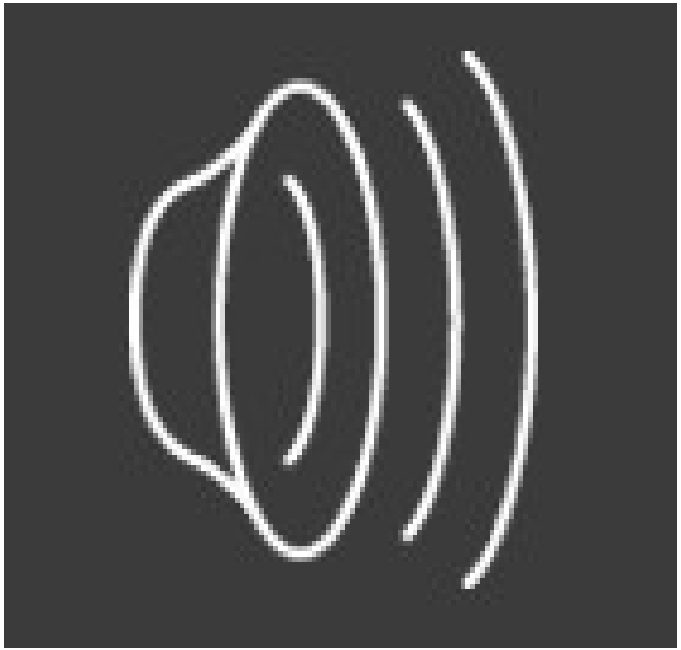
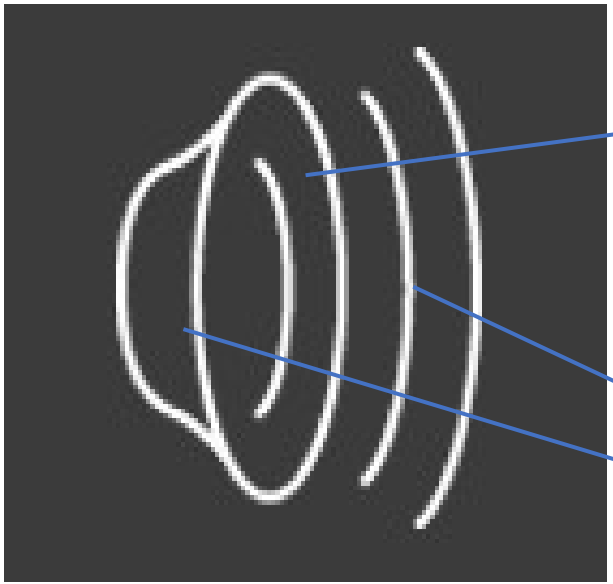
Dynamic Contrast Enhanced MRI (DCE-MRI)

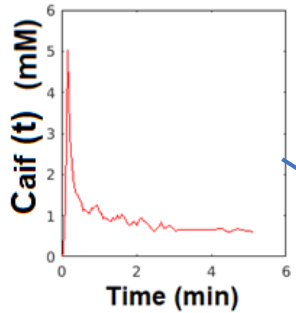


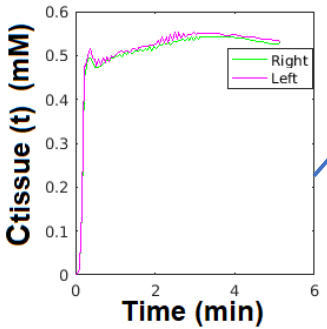
- Estimating glomerular filtration rate (GFR) is crucial for diagnoising hydronephrosis
- Dynamic contrast-enhanced (DCE) – MRI is a promising tool to estimate tracer kinetic (TK) parameters
  - Filtration rate of kidneys

Dynamic Contrast Enhanced MRI (DCE-MRI)

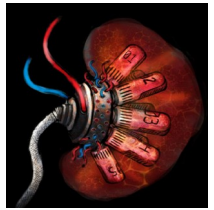
- **DCE-MRI** □ filtration rate of kidneys







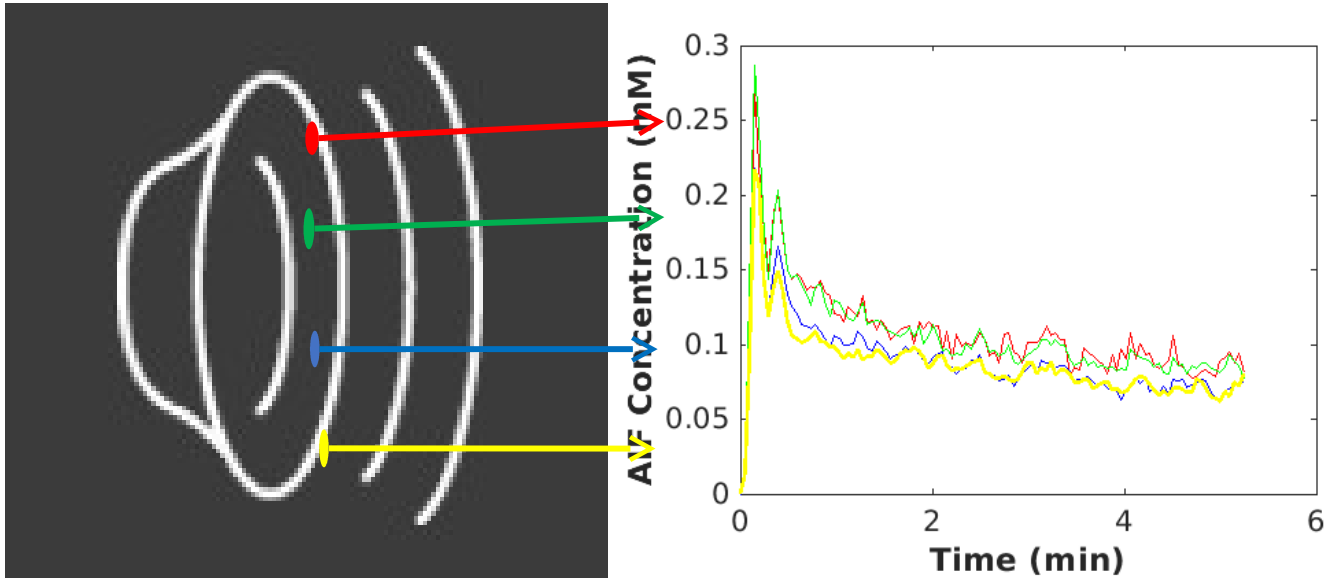
Tracer Kinetic Parameter Model Fitting



Filtration rate

DCE-MRI

- **DCE-MRI** □ filtration rate of kidneys
- **Problem:** Measuring/selection arterial input function (AIF) is challenging



A slight deviation in the AIF can significantly alter the estimation of kinetic parameters

- **Goal:** Improve AIF selection for estimating kidney function

DCE-MR Image Acquisition

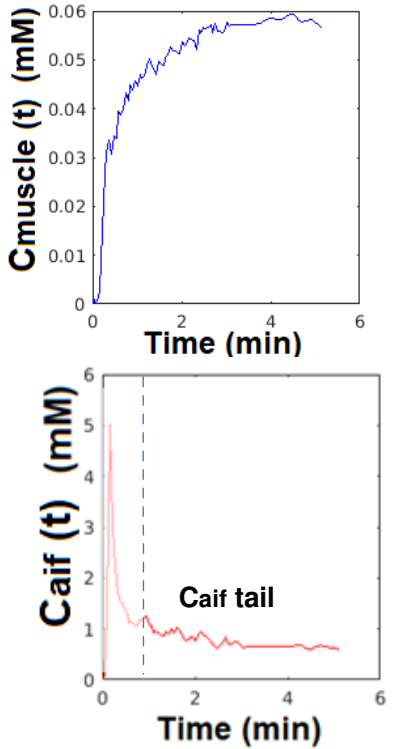
- DCE-MR images from five patients who had a nuclear medicine GFR test and who are undergoing a contrast-enhanced MRI exam using an approved IRB protocol
- “Stack-of-stars” 3D FLASH prototype sequence with a multi-channel body-matrix coil
- 3T Siemens Skyra/Trio
- TR/TE/FA=3.56/1.39ms/12°
- 32 coronal slices
- Voxel size=1.25x1.25x3mm^3
- 1326 radial spokes acquired in 6 mins with golden angle radial ordering
- Average temporal resolution=3.3 s

Estimation of TK Parameters with a Reference Region and AIF Tail

- Estimate tracer kinetic (TK) parameters of extended Tofts Model (K_{trans}, k_{ep}, V_p) without sensitivity to AIF

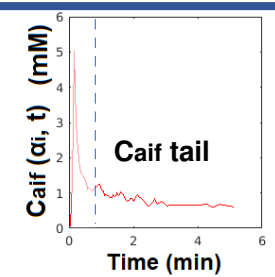
 Reference region and input function tail (RRIFT) [1]

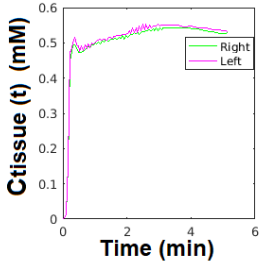
  - Reference region concentration (Psoas muscle)
  - Tail of the AIF

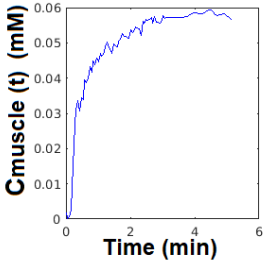


[1] Ahmed, Z. and Levesque, I.R., 2020. Pharmacokinetic modeling of dynamic contrast-enhanced MRI using a reference region and input function tail. Magn Resonance in Medicine, 83(1), pp.286-298

Optimization of AIF Parameter α_i





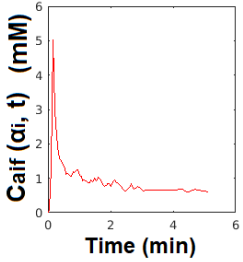


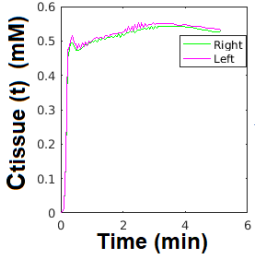
α_i is the percentile of peak values

$C_{aif}(\alpha_i, t)$ is concentration volume average of aorta voxels with α_i percentile peak values

RRIFT

K_{trans}REF
k_{ep}REF
V_pREF





k_{ep}REF
V_pREF

Extended Tofts Model (ETM) [2, 3]

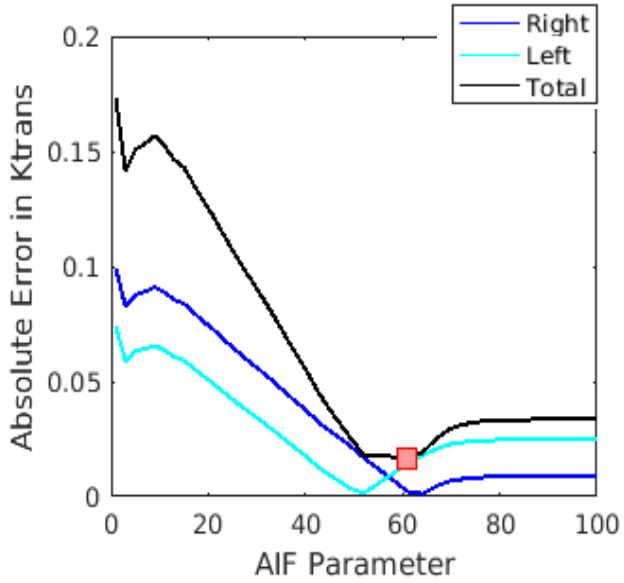
K_{trans}ETM

[2] Tofts PS. Modeling tracer kinetics in dynamic Gd-DTPA MR imaging. J Magn Reson Imaging. 1997;7(1):91-101.
[3] Tofts PS, Brix G, Buckley DL, et al. Estimating kinetic parameters from dynamic contrast-enhanced T1-weighted MRI tracer: standardized quantities and symbols. J Magn Reson Imaging. 1999;10:223-232.

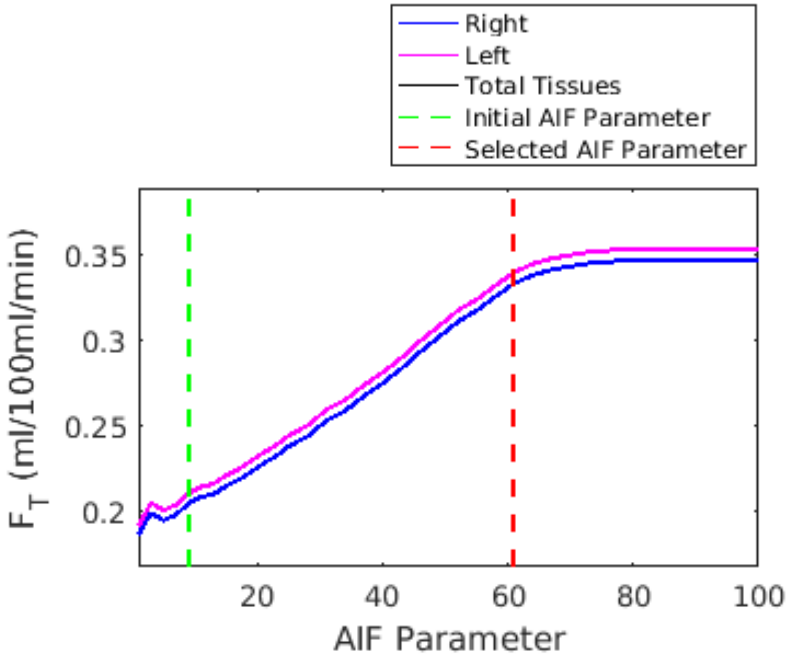
Optimization of AIF Parameter α_i

$$\alpha_{sel} = \arg\min_{\alpha_i} \sum_k |Ktrans_{ETM}(k, \alpha_i) - Ktrans_{REF}(k, \alpha_i)|$$

"k" is the tissue index (k=1 right kidney, k=2 left kidney)

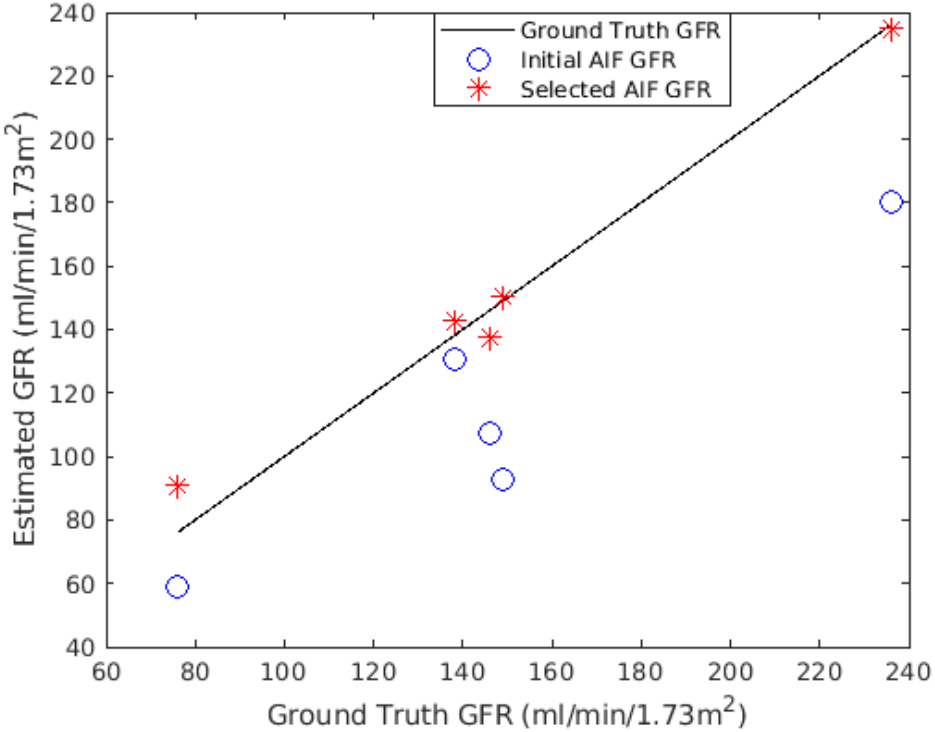


Model Fitting using 2 – Compartment Model [4]



[4] S. P. Sourbron, H. J. Michaely, M. F. Reiser, and S. O. Schoenberg, “MRI-measurement of perfusion and glomerular

Glomerular Filtration Rate (GFR)



With the proposed AIF selection method, the mean absolute error in GFR was reduced from 34.9 to 6.1

Discussion and Conclusion

- A slight deviation in the AIF alters estimated tracer kinetic parameters significantly
- Reference region and AIF tail concentrations were employed to improve the selection of AIF for GFR estimation of kidneys using 2-CP model
- Comparing the estimated GFRs with the ground truth GFRs measured by nuclear medicine (DTPA-GFR), the mean absolute error in GFR was reduced from 34.9 to 6.1
- A similar pipeline can be used to optimize an AIF parameter based on segmentation region or parametric equation

Acknowledgements

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