Convex Optimization-Based Compartmental Pharmacokinetic Analysis for Prostate Tumor Characterization Using DCE-MRI

Additional Simulations

It is true that the temporal resolution affects the accuracy of the estimated parameters, as the principle ideology behind the COKE algorithm is to effectively exploit this temporal diversity. For the very same reason, in the simulations a time resolution of 4 seconds has been adopted. However, in real DCE-MRI measurement protocol, the time resolutions are maintained to be 30 seconds, as the radiologists believe that the observations with a higher time resolution (less than 30 seconds) could not divulge more information regarding the underlying changes. Hence, for T1-weighted images (as the one used in this work), the time resolution is standardized to be 30 seconds. Also, as the contrast agents are naturally washed away due to blood circulation, in about 10 - 12 minutes, the DCE-MR imaging protocol for prostate cancer could produce only about 20 to 24 time-series images per slice.

To study the impact of the variation in time resolution and the practical validity of the AIF estimation procedure, we have conducted the simulation experiments for several varying time resolutions (with varying SNRs) using the AIFs, and FRCs that have been estimated for Patients A and B. Since the FRCs used in the simulations conclude a severe cancer, in the simulations the random tissue maps are generated based on Scenario 3, defined in Section IV of the manuscript. The results are tabulated in Tables 1 and 2, below. The respective FRCs used in this simulation, for each Patient is also mentioned in these two tables. It can be readily observed from the results that the higher the time resolution is, the better are the estimated parameter values. It is important to observe that even for a temporal resolution of 30 seconds (which is the case with the real data experiments), the estimates are still reasonably close to the true values, especially for high SNRs. As the modern day MRI sensors are capable of offering better SNRs, the reliability and practical applicability of the proposed COKE methodology can therefore be justified.

Table 1: Mean±standard deviation of the estimated flux rate constants $(\widehat{k}_{\mathrm{ep},f}, \widehat{k}_{\mathrm{ep},s})$ obtained by COKE over 50 independent runs, for different random tissue maps and different SNRs. The AIF obtained for Patient A is used in this simulation, with the $k_{\mathrm{ep},f} = 0.6495$ and $k_{\mathrm{ep},s} = 0.1451$ (obtained from Slice 17, Table IV).

SNR	$\widehat{k}_{\mathrm{ep}}$	$\Delta t = 10$ **seconds**	$\Delta t = 20$ **seconds**	$\Delta t = 30$ **seconds**
40 dB	$\widehat{k}_{\mathrm{ep},f}$	0.6261±0.0643	0.6043±0.0676	0.5954±0.0721
	$\widehat{k}_{\mathrm{ep},s}$	0.1456±0.0056	0.1465±0.0087	0.1443±0.0120
35 dB	$\widehat{k}_{\mathrm{ep},f}$	0.6144±0.0799	0.5721±0.1123	0.5680±0.0941
	$\widehat{k}_{\mathrm{ep},s}$	0.1389±0.0081	0.1483±0.0069	0.1501±0.0090
30 dB	$\widehat{k}_{\mathrm{ep},f}$	0.5843±0.0841	0.5609±0.0980	0.5512±0.1240
	$\widehat{k}_{\mathrm{ep},s}$	0.1306±0.0103	0.1419±0.0126	0.1570±0.0214

Table 2: Mean±standard deviation of the estimated flux rate constants $(\widehat{k}_{\mathrm{ep},f}, \widehat{k}_{\mathrm{ep},s})$ obtained by COKE over 50 independent runs, for different random tissue maps and different SNRs. The AIF obtained for Patient B is used in this simulation, with the $k_{\mathrm{ep},f} = 0.2986$ and $k_{\mathrm{ep},s} = 0.0786$ (obtained from Slice 18, Table IV).

SNR	$\widehat{k}_{\mathrm{ep}}$	$\Delta t = 10$ **seconds**	$\Delta t = 20$ **seconds**	$\Delta t = 30$ **seconds**
40 dB	$\widehat{k}_{\mathrm{ep},f}$	0.2902±0.0230	0.2914±0.0365	0.2861±0.0276
	$\widehat{k}_{\mathrm{ep},s}$	0.0941±0.0028	0.0893±0.0054	0.0862±0.0084
35 dB	$\widehat{k}_{\mathrm{ep},f}$	0.2853±0.0189	0.2866±0.0328	0.2601±0.0299
	$\widehat{k}_{\mathrm{ep},s}$	0.0923±0.0124	0.1034±0.0011	0.0824±0.0015
30 dB	$\widehat{k}_{\mathrm{ep},f}$	0.2709±0.0141	0.2691±0.0431	0.2435±0.0419
	$\widehat{k}_{\mathrm{ep},s}$	0.0897±0.0089	0.0982±0.0074	0.0758±0.0039