A new constrained blind estimation algorithm for determination of the arterial input function without reference tissues

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Introduction: A major challenge in dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) is the need to provide a measured estimate of the arterial input function (AIF) in order to perform pharmacokinetic modeling analysis of the resulting data. Measurement of the AIF requires the presence of a major artery in the imaging field-of-view, a significantly faster sampling rate than for tissue curve measurement, and a large dynamic range for accurate first-pass bolus quantification. AIF measurements can be confounded by signal saturation effects, partial-volume effects, and inflow and pulsatility artifacts, to name a few issues. In addition, in the brain it is known that there are local variations in AIF, highlighting the fact that the AIF in a nearby major artery may not accurately reflect the true local blood flow to tissues (1). For these reasons, development of a method of blind estimation of the AIF directly from measured tissue time curves is highly attractive (2). Here, we describe a novel, efficient, and practical approach for blind AIF estimation without use of reference tissues that is capable of recovering realistic AIFs from tissue curves alone in both simulated and real data with signal-to-noise ratios (SNR) typical for DCE-MRI data *in vivo*.

Methods: Synthetic tissue concentration-time curves were generated by selecting values of the pharmacokinetic parameters from uniform random distributions so that $K^{trans} \in (0,1]$, $v_e \in (0.15,1]$, and $v_p \in (0,0.2]$ and Monte Carlo simulations performed to verify performance of the blind algorithm. A model functional form for the AIF based on population data from (3) was used (see (4) for details):

$$C_p(t) = A_0 S(t-\Delta_0,\alpha_0,\tau_0,T_0) + \sum_{n=1}^{3} A_n G(t-\Delta_n,\alpha_n,\tau_n) \qquad (1)$$

and tissue concentration was computed using FFT convolution with the extended Tofts-Kety compartment model :

$$C_t(t) = K^{trans} C_p(t) \star e^{-k_{ep}t} + v_p C_p(t) \qquad (2)$$

The patient data presented in this abstract was measured at 1.5T in the distal thigh of a sarcoma patient under an IRB-approved protocol using a 3D spoiled gradient echo acquisition. Acquisition parameters were : TR=3.01 ms, TE=1.14 ms, alpha = 20, voxel size 2x2x2 mm. Acquisition time was 5.5 s per frame. Signal data was converted to concentration using the methods described in (4). The measured AIF estimate was computed from voxels selected from the femoral artery in a conventional way (3). AIF is blindly estimated by selecting a set of tissue curves within a tumor ROI that excludes arterial and venous voxels for which mean post-injection contrast concentration was at least 0.5 mM. In this patient, this resulted in 9626 curves, a subset of which are shown in Fig. 1. Groups of five tissue curves were selected at random from this pool and simultaneously fit with the model of Eq. 2, using the AIF parameterization of Eq. 1, to provide an AIF estimate. This process was repeated 100 times and the final AIF estimate determined by taking the median of these estimates at each time point.

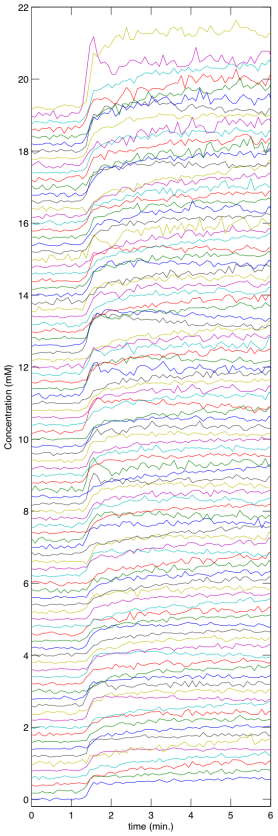

Figure 1. 1% of the tumor tissue curves used as input to the blind estimation algorithm, sorted by mean post-injection contrast concentration. Successive curves are offset by 0.2 mM

Results: A subset of the tissue curves constituting the pool from which our blind estimation algorithm drew are plotted in Figure 1, with successive curves offset by 0.2 mM for clarity. The blind estimate of the AIF (blue) is compared with the measured AIF (red) in the leftmost panel of Figure 2. Maps of K^{trans} computed for a single slice of the measured data using these AIFs are shown in the right hand panels. The method described has been studied in approximately 15 other sarcoma patients, with similar results.

Discussion: The tissue curves plotted in Figure 1 are typical of single voxel DCE-MRI data in tumors and are free of obvious arterial or venous contamination, indicating that our blind estimation algorithm is capable of functioning well on realistic measured data. As Figure 2 indicates, we are able to recover an AIF from the blind estimation that is quite similar in shape, both in the first-pass peak and in the tail, to the measured AIF. There is a small (roughly 3 s), but noticeable time delay between the blind and measured AIFs that may represent the physical transit time of the bolus from the femoral artery where the AIF was measured to the tumor tissues used for blind AIF estimation.

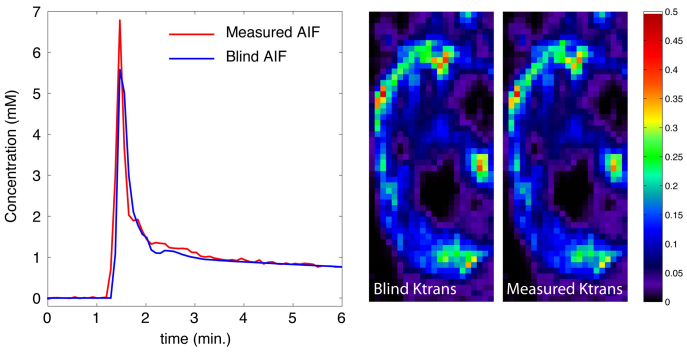

Figure 2. Comparison of blind (blue) and measured (red) AIF estimates (left panel), along with resulting maps of K^{trans} (right panels).

References

1. C Lorenz *et al., J. Magn. Reson. Imag.* 2006 **24** 57-65.
2. DY Riabkov *et al., Phys. Med. Biol.* 2004 **49** 639-664.
3. GJM Parker *et al., Magn. Reson. Med.* 2006 **56** 993-1000.
4. MC Schabel *et al., Phys. Med. Biol.* 2008 **53** 2345-2373.