Interleaved Acquisition of a Radial Projection Based AIF with a Multi-slice DCE Experiment

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Target Audience: Researchers performing Dynamic Contrast-Enhanced MRI in mice requiring a high temporal-resolution arterial input function (AIF).

Purpose: DCE MRI is a popular technique for studying cancers [1]. Quantitative information about the tumour vasculature may be determined through pharmacokinetic modelling [2]. Typical models use the contrast agent concentration-time curves in both the tissue of interest and in a blood vessel supplying this tissue as input parameters [3]. The blood based curve, referred to as the arterial input function (AIF), is difficult to measure in rodents due to their rapid heart rates [4], and limited number of sufficiently large blood vessels near the tumour [5]. Our group has shown that a high temporal-resolution AIF (ΔT = 100 ms) may be acquired in the mouse tail, using a projection based method [6]. This study looks at the potential of interleaving our AIF measurement with a multi-slice DCE MRI experiment [7].

Methods: MRI data acquisition took place on a Biospec 70/30 Bruker 7.0 T MRI system. Signal excitation was provided by a birdcage coil (inner diameter 7.0 cm), and an actively decoupled strip-line coil (width 7 mm, length 18 mm) was used for data acquisition. Two slice packs were defined: one (single slice) for the AIF, and one (multi-slice) for the DCE tumour concentration measurement. A mouse-tail phantom, consisting of a capillary tube (inner diameter 0.4 mm) inserted into a larger glass tube (inner diameter 3.7 mm), was scanned. The space between the tubes was filled with tap water to provide additional signal for shimming and a non-enhancing background. The AIF slice was oriented perpendicular to the capillary tube to maximize the SNR and minimize fringe fields [8]. For purposes of method development, the DCE study was performed on the static water background of the phantom, but offset from the AIF slice 8 mm along the z-axis.

The AIF was measured with a flow-compensated radial FLASH protocol (TR/TE = 100 ms/5 ms, flip angle 30°, 15x15 mm^2 FOV, 256 read encode steps). The angular increment was set for Golden angle sampling ($\Delta\theta = 111.25°$) [9] for 233 unique angles. The DCE slices were acquired with a Cartesian FLASH sequence (TR/TE = 100 ms/5 ms, flip angle 30°, 15x15 mm^2 FOV, 256x256 matrix size). The scan was repeated for 50 acquisitions, for a total scan time of 21 min and 20 sec. For each repetition time, the pulse program acquired one line of k-space for the AIF, followed by one line of k-space for each DCE slice.

We simulated an AIF using a flow phantom inspired by Akbudak et al., [10]. A peristaltic pump (Minipuls 2, Gilson) controlled the flow rate of tap water in the tubing. The system had an initial volume of 23.0±0.5 mL, and included an injection port for the contrast agent injection. A 1.00 mL bolus of 30 mM Multihance contrast agent (Bracco Diagnostics), mixed in saline, was injected approx. 40 s after the start of the scan, at a rate of 5.00 ml/min with a kd Scientific power injector (model 780220). The bolus was allowed to circulate continuously for the remainder of the scan. The AIF was determined following the procedure outlined in [6], but extended to accommodate each of the 233 unique angles [11].

Results/Discussion: Figure 1 shows the measured radial AIF (ΔT = 100 ms) and one post-injection DCE slice (ΔT = 25.6 s). We see a series of concentration peaks, resulting from the recirculation of the contrast agent, after mixing in a small beaker (~3mL volume) each pass. Due to the walls of the capillary tube being glass, we were unable to simulate a DCE experiment for this study. The DCE image shown in the inset displays the spatial resolution (59 µm) attained with our technique.

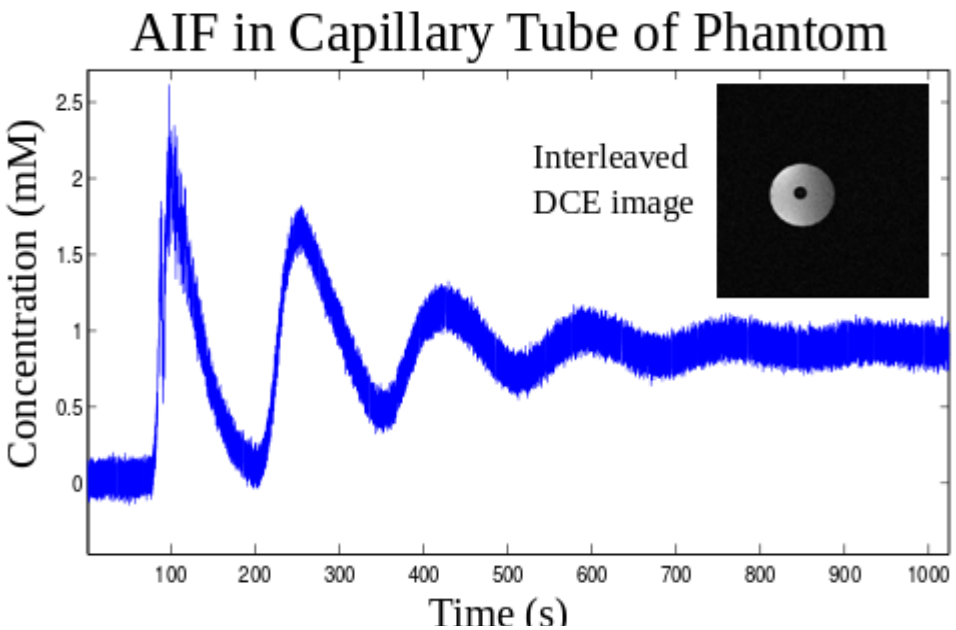

Figure 1: Radial AIF measured in the capillary tube of tail phantom (mean filtered with 5 data points). The contrast agent circulates around the system for the duration of the scan, mixing with additional tap water each cycle to provide recirculation peaks. The inset shows a DCE MRI image acquired simultaneously with the AIF. The spatial resolution of the DCE image is not compromised by the added AIF measurement.

Accurate modelling of DCE data requires that an AIF be measured during each experiment. However, this is not always achievable in animal based studies, forcing researchers to use an assumed mathematical function [12] or a population averaged curve [13]. By interleaving a projection-based AIF measurement with a DCE MRI experiment, we are able to maintain a satisfactory temporal resolution of the DCE data (25.6 s) without compromising image quality. Though the tail vein may not directly supply the tumour, it will provide a better approximation of the true blood concentration feeding the tumour, thus improving the accuracy of the fit parameters.

Utilizing a radial sampling scheme for the AIF has three main advantages: 1) we can investigate, and correct for, local tissue enhancement in the tissue surrounding the vessel [11], 2) reconstructed radial images provide a secondary check of the concentration when the curve starts to plateau, and 3) radial images may be reconstructed with multiple temporal resolutions, by using a different numbers of projections in the reconstruction, thereby providing more information about the size and rate of enhancement. A simulation study investigated the presence of multiple vessels in the imaging plane was also performed. The results suggest that the AIF can still be measured accurately, but it is best to avoid angles where there is significant overlap between two vessels in the projection (results not shown).

Conclusions: This study shows that interleaving our AIF measurement with a DCE-MRI experiment is possible without compromising the temporal resolution of either. Future developments will explore parallel imaging approaches for faster DCE image acquisition, and coil development such that a single-element receive coil can be used for AIF and a phased array coil for tumour data acquisition.

Acknowledgements: This project was made possible by funding from NSERC and the BC Cancer Agency.

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