DCE-MRI in tumors at 11.7 Tesla requires the estimation of arterial input function by phase imaging instead of magnitude imaging

A-C. Fruytier[1], J. Magat[1], B. F. Jordan[1], G. Cron[2], and B. Gallez[1]
[1]Louvain Drug Research Institute, Biomedical Magnetic Resonance Research Group, University of Louvain, Brussels, Belgium, [2]Ottawa Health Research Institute, Ottawa, Canada

Purpose

Ultra-High-field MRI and MRS are invaluable tools in cancer research and characterization of the tumor micro-environment, allowing very high SNR and high spectral resolution. DCE-MRI allows a non invasive assessment of the tumor hemodynamics. For the determination of quantitative parameters through pharmacokinetic modelling, the arterial input function (AIF) should be measured accurately. In this work, we show that, at 11.7 Tesla, T2* relaxation has a major effect on arterial signal, causing magnitude imaging to fail to provide a proper measurement of the AIF. We acquired a time sequence of T1w images after an i.v. bolus of the contrast agent Gd-DOTA (Dotarem®) and noted a large, undesireable dip in arterial signal magnitude at early time points (AIF first-pass). We therefore decided to focus our work on characterization of the AIF using phase imaging. Earlier work has suggested that phase imaging can more reliably characterize the AIF, due to phase's linear relationship with concentration (without contamination from T1 or T2 effects), greater SNR, and reduced vulnerability to partial volume effects (1-3). To validate our phase technique, we conducted an in vitro study with a phantom consisting of tubing mimicking the iliac artery of the mice (where the AIF is measured in vivo). We measured the phase shift (ΔØ) as a function of different concentrations of Gd-DOTA.

Material and methods

Five NMRI mice bearing 8-mm diameter tumors (TLT hepatocarcinoma) were used. Gd-DOTA was injected into the tail vein as a bolus (0.33 mmol Gd/kg). MRI experiments were performed with a 11.7T Bruker Biospec and quadrature volume coil (inner diameter 40mm, length 100mm). A FLASH sequence was used to measure AIF in vivo: single transverse slice, TE=2.074 ms, TR=15.000 ms, $\alpha = 40.0°$, FOV=30 mm, matrix 128x64, zero-fill acceleration factor of 1.4, spatial resolution= 0.234 mm/pixel - 0.469 mm/pixel, temporal resolution of 1.19s. To reduce partial volume artefacts, a central pixel in the artery was selected. When phase aliasing occurred, a manual correction (adding 2π) was done. To mimic the in vivo situation, a closed-loop flow system was constructed, consisting of tubing connected to a pump and a flask with a mixing device (Fig. 4). The tubing diameter and flow rate were 0.51 mm and 0.53 ml/min, approximately matching those of the mouse iliac artery. The tubing was parallel with the main magnetic field and surrounded by a syringe filled with D_20. The same sequence used for the in vivo experiments was used to measure the phase shift at steady state after serial addition of contrast agent into the mixing device. The steady state ΔØ was measured by subtracting the baseline phase from the steady state phase following contrast agent administration.

Results

In tumour, we observed a large positive enhancement on magnitude images (Fig. 1). Fig.2 shows typical magnitude data, from a time series of T1w images, measured in the mouse iliac artery. The negative enhancement demonstrates a major contribution of the susceptibility effect of the contrast agent at this high magnetic field. When using phase imaging in the same conditions, we observed a clear positive bolus peak (Fig. 3). The phantom constructed in the MRI system (Fig. 4) allowed us to measure the relationship between the ΔØ and the Dotarem® concentration (Fig. 5).

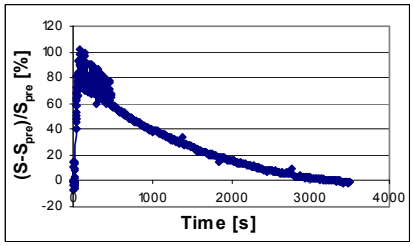

Fig.1 : T1-weighted magnitude imaging in tumour (0,33 mmol Gd/kg)

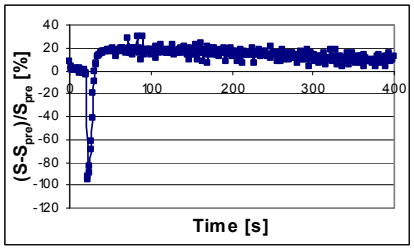

Fig. 2 : T1-weighted magnitude imaging in mouse iliac artery (0,33 mmol Gd/kg)

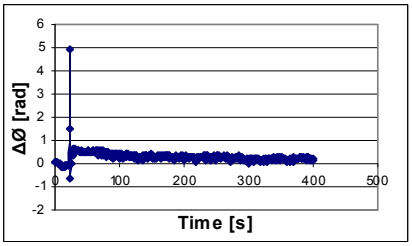

Fig. 3: Phase imaging in mouse iliac artery (0,33 mmol Gd/kg)

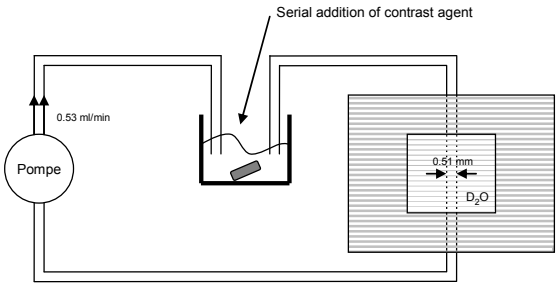

Fig. 4: Phantom system

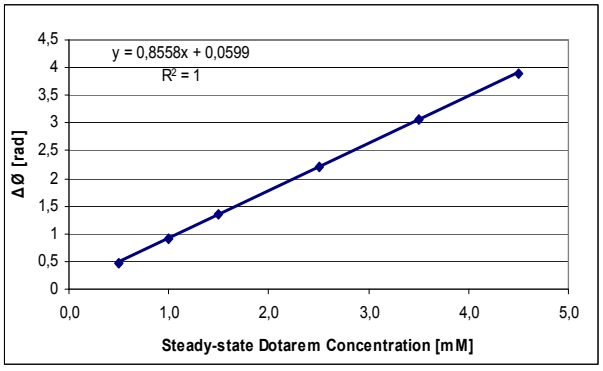

Fig. 5: Phase shift versus steady-state Dotarem® concentration

Conclusions:

Phase imaging appears to provide the best opportunity for measuring the AIF at 11.7 Tesla. The calibration curve obtained in vitro will be used to measure contrast agent concentration in the mouse iliac artery for future DCE-MRI experiments.

References:

(1) Magn Reson Im. 2005;23:619-627
(2) Magn Reson Med. 1997;38:990-1002
(3) Magn Reson Med. 1996;36:809-815