A Comparison of Arterial Input Functions Derived from Phase and Magnitude for Quantitative DCE-MRI of the Prostate

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Introduction: Quantitative dynamic contrast-enhanced (qDCE) MRI is an evolving experimental technique used to measure perfusion in a tissue of interest (e.g. tumor). qDCE-MRI involves intravenous injection of a Gd-based contrast agent followed by rapid, repeated T_1-weighted MR imaging. These data are used to estimate the arterial input function (AIF) and tissue response function (TRF), which are then modeled to obtain tracer kinetic parameters such as the volume transfer constant (K^{trans}) and leakage space (v_e). K^{trans} and v_e have promising diagnostic potential for a variety of diseases such as prostate cancer (1-5). For prostate studies, the magnitude signal ($|S|$) inside the iliac arteries may be used to obtain the AIF. However, these AIF measurements may be confounded by flow effects, T_2^* effects, and saturation of $|S|$ at high contrast agent concentrations. Previous studies have suggested that changes in phase ($\Delta\phi$) may be superior to $|S|$ for estimating the AIF (6-9). The purpose of this work was to determine if AIFs derived from $\Delta\phi$ provide more stable estimates of K^{trans} and v_e for qDCE-MRI of the prostate. As a first step in this investigation, patient-to-patient variations in K^{trans} and v_e in a reference tissue (obturator internus muscle) were measured using phase-derived AIFs versus conventional magnitude-derived AIFs in 9 patients (10-11).

Methods: qDCE-MRI of the human prostate (n=9) was performed at 1.5T using a 3D spoiled gradient echo pulse sequence with TR=5.8 ms, TE=2.56 ms, FA=35°, 20 transverse (axial) slices, matrix=256x224, FOV=25x22 cm, Δz=5 mm, Δt=14.6 s, 0.2 mmol/kg Gadovist, complex (raw) data saved during acquisition. $\Delta\phi$ as a function of time [$\Delta\phi(t)$] and $|S(t)|$ were computed for every voxel inside the lumina of the iliac arteries for all 20 slices. Average $\Delta\phi(t)$ and $|S(t)|$ curves were computed from these voxels. Iliac artery lumina voxels were rejected from the AIF computation if $\Delta\phi(t)$ and $|S(t)|$ were poorly temporally correlated (r<0.5, similar to Eq. 11 in ref 9). $\Delta\phi(t)$ was converted to a whole-blood phase-derived AIF *via* the factor 11.2 mM/rad, which takes into account the field strength, TE, and geometry of the iliac arteries (7). Standard gradient echo signal strength equations were used to convert iliac artery $|S(t)|$ to a whole-blood magnitude-derived AIF and muscle $|S(t)|$ to TRF (assumed $T_{1,blood,pre\text{-}Gd}$ = 1250 ms, $T_{1,muscle,pre\text{-}Gd}$ = 900 ms) (11). For each patient, the muscle TRF was analyzed with either the phase-derived AIF or magnitude-derived AIF to compute K^{trans} and v_e (Eq. 1 in ref 11, assuming fast exchange limit and small-vessel hematocrit=0.25).

Results: Across all patients, phase-derived AIFs gave muscle K^{trans}=0.048 ± 0.058 min^{-1} (122% patient-to-patient variation), v_e=0.048 ± 0.017 (36%) whereas magnitude-derived AIFs gave K^{trans} = 0.122 ± 0.172 min^{-1} (141%), v_e = 0.181 ± 0.108 (60%).

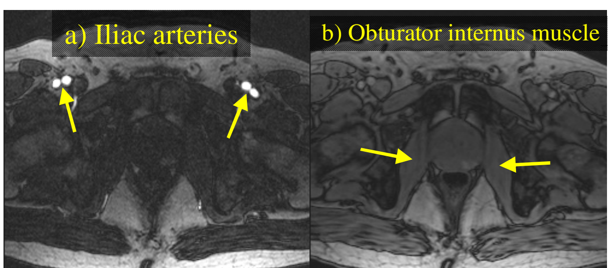

Fig. 1: Example arteries & muscle used for AIF & TRF

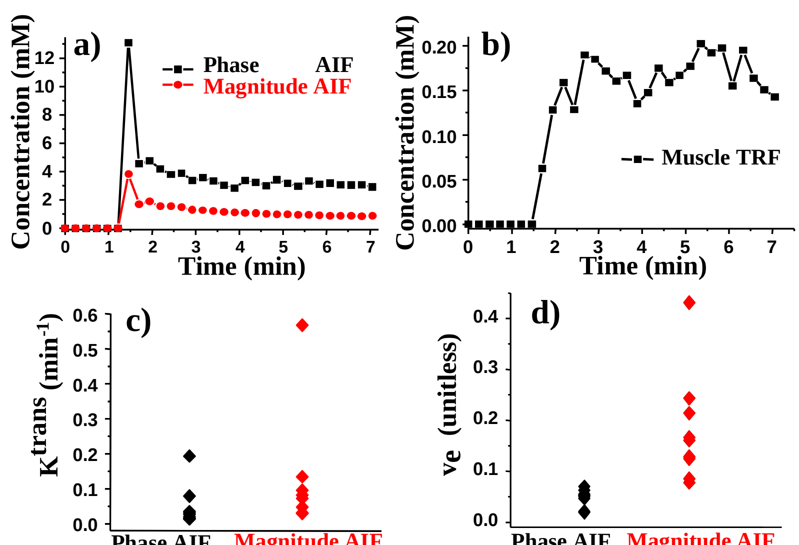

Fig. 2: Plasma AIFs (a), muscle TRF (b) for one patient. Computed K^{trans} (c) and v_e (d) for obturator internus muscle for all 9 patients.

Discussion: Compared to magnitude AIFs, phase AIFs resulted in 15% less variation in K^{trans} in muscle and 66% less variation in v_e. Patient-to-patient variations in K^{trans} were relatively high for both AIFs (122-141%), however, which may be due to difficulty in characterizing the AIF peak with a temporal resolution of 14.6 s.

Conclusion: For qDCE-MRI of the prostate, phase-derived AIFs resulted in 15% less patient-to-patient variation in computed values of K^{trans} and 66% less variation in v_e for obturator internus muscle. It is therefore expected that phase-derived AIFs will provide more stable measurements of K^{trans} and v_e in prostate tumors.

References: 1.Kozlowski JMRI 24:108. 2.Buckley Radiology 233:709. 3.Ocak AJR 189:W192. 4.Vos Med Phys 35:888. 5.van Dorsten JMRI 20:279. 6.Engelbrecht Radiology 229:248. 7.Cron MRI 23:619. 8.Kotys JMRI 25:598. 9.van Osch MRM 45:477. 10.Padhani NMR Biomed 15:143. 11.Yankeelov MRM 57:353.