The use of Phase to Measure the Arterial Input Function for Quantitative T1-weighted DCE-MRI in Human Brain Tumors

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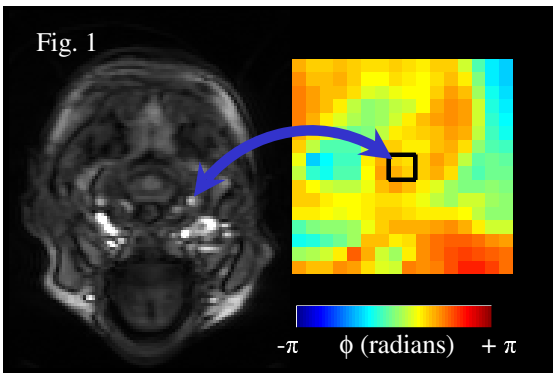
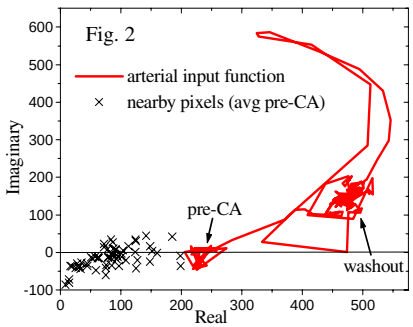
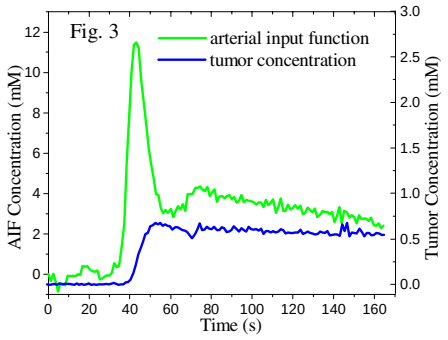
Introduction: Measuring perfusion quantitatively in brain tumors with dynamic contrast-enhanced T_1-weighted (DCE T_1w) MRI has been an active area of research (1). For such studies, measurement of the arterial input function (AIF) in large vessels may be confounded by flow effects or saturation of the magnitude signal ($|S|$) at high contrast agent concentrations ([CA]) (2). Previous studies have suggested that changes in phase ($\Delta\phi$) may be superior to $|S|$ for estimating the AIF (3,4). $\Delta\phi$ does not saturate at high [CA], is relatively insensitive to moderate blood flow velocities (~15 cm/s), provides higher contrast-to-noise ratio compared to $|S|$, and has a well-known relationship to [CA] in vessels parallel to the main magnetic field ($\parallel$ to B_0) (3,4). Thus, for DCE T_1w MRI of brain tumors, we propose retaining the complex data during the dynamic acquisition and computing phase changes ($\Delta\phi$) in a major vessel $\parallel$ to B_0 to estimate AIF. We show a clinical example of this technique for measuring perfusion (K^{trans}) in a human brain tumor.

Methods: DCE T_1w MRI was performed at 1.5T using a 2D spoiled gradient echo (SGRE) pulse sequence with TR=25 ms, TE=2.06 ms, FA=90°, transverse (axial) slices, matrix=96x128, FOV=17x23 cm, Δz=5 mm, Δt=1.2 s, Gd dose=0.2 mmol/kg. Four slices covered the tumor volume and one slice was placed through the carotid artery in a location where the artery was $\parallel$ to B_0. Additionally, 3D SGRE images with TR=50 ms, TE=2.16 ms, FA=(10°,20°,40°) were used to measure tumor T_1 pre- and post-contrast to convert $|S|(t)$ to [CA](t) (5,6). The complex data were converted to $\Delta\phi$ and used to calculate the AIF in the carotid artery (3). Tracer kinetic modeling was performed on the AIF and tumor [CA](t) pixel-by-pixel to give a map of the volume transfer constant (K^{trans}) (1).

Results: Fig. 1 shows a magnitude image of the location chosen for the AIF, as well as a pre-contrast phase map of neighboring pixels. Fig. 2 shows a polar plot of the complex data in the carotid artery which were used to compute the AIF, as well as the pre-contrast complex values of nearby pixels ($\leq$ 3 pixels away). Owing to the sinc point spread function, neighboring pixels may contribute to the signal in the carotid artery, confounding AIF measurements (7). From Fig. 2, however, there are no nearby pixels of significant magnitude which are $\pi/2$ out of phase with the carotid AIF pixels. This fact, combined with the enhancement (increased $|S|$) of the carotid pixels with increasing [CA], suggests that neighboring pixels will not significantly affect the measured AIF. Fig. 3 shows the AIF and whole-tumor [CA](t). Fig. 4 shows the tumor K^{trans} map (center slice) overlaid on a T_2w image of the same slice.







Discussion: When measuring perfusion quantitatively in tumors with DCE T_1w MRI, it can be challenging to measure the AIF in large vessels. Blood flow and saturation effects (related to both T_1 and T_2*) can lead to incorrect conversion of signal magnitude to contrast agent concentration (3). The signal phase, however, is largely immune to such effects, potentially providing improved AIF measurement with no added imaging time or pulse sequence modification. The use of phase data to measure the AIF for tumor perfusion has already shown utility in animals studies (8). Here, we applied this AIF technique to quantitative perfusion in the human brain. The measured concentrations in the AIF (for a Gd dose of 0.2 mmol/kg) and K^{trans} in the tumor are consistent with literature values, warranting futher study of this technique.

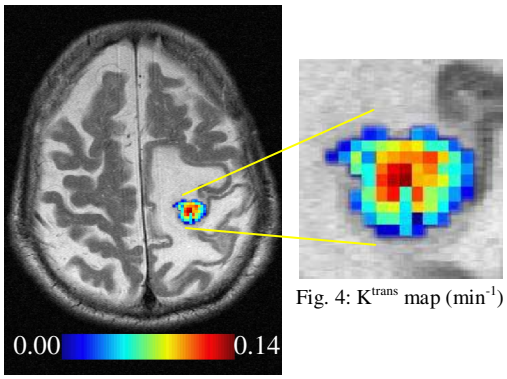


Fig. 4: K^{trans} map (min^{-1})

References: 1. Cha, AJNR 27:475 (2006). 2. Mikkelsen et al, Proc ISMRM 15: 3501 (2007). 3. Cron et al, MRI 23:619 (2005). 4. Kotys et al, JMRI 25:598 (2007). 5. Deoni et al, MRM 49: 515 (2003). 6. Cron et al, MRM 51 :1066 (2004). 7. van Osch et al, MRM 45: 477 (2001). 8. Yankeelov et al, MRM 57: 353 (2007).