

Feasibility of arterial input functions from phase data in T₁-weighted dynamic contrast-enhanced MRI

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Introduction

The accuracy in pharmacokinetic parameters derived from Dynamic Contrast-Enhanced MRI (DCE-MRI) depends strongly on the quality of the arterial input function (AIF). The AIF is challenging to measure accurately for several reasons. For example, T₁ needs to be determined with a temporal resolution of about one second and with a spatial resolution high enough to resolve the artery where the AIF is sampled. These two conflicting demands will result in low SNR. In addition, inaccuracies are also likely to occur due to in- and outflow effects [1] as well as signal saturation at high concentrations.

Inversion and saturation prepared Gradient Echo (ir/sr-GRE) sequences are frequently used in DCE-MRI since they offer a high degree of T₁-weighting. Optimizing these sequences is difficult since they are either optimized for the concentration levels in the region of interest (e.g. a tumor) or for the concentration levels in blood.

Only the magnitude is currently used for determination of the contrast agent concentration derived from ir/sr-GRE sequences. However, Dynamic Susceptibility Contrast MRI studies have shown that the phase information also can be useful for determination of the AIF [2]. The phase has the benefits that it can be used to measure a much wider range of concentrations, is less sensitive to flow effects, and that partial volume effects can be corrected for in some cases [3].

The aim of this study was to determine if the phase information from a non-selective sr-GRE sequence optimized for the contrast levels in a tumor can be used for measurement of the AIF.

Method

The study was conducted on a pulsatile flow-phantom to mimic a real measurement situation and still have full control over contrast concentration levels. The phantom consisted of a water filled cylinder through which a tube of 6mm diameter passed. Water doped with Magnevist flowed through the tube with velocities ranging from 0 to 40cm/s in each simulated cardiac cycle of 0.86s. The true concentration in the phantom was estimated from the dynamics of the flow-phantom and the injection rate. To reduce influences from unknown dynamics, such as the flow profile in the hoses connecting the phantom to the pump, the adding of contrast was performed very slowly during 2 hours. The tube inside the phantom was oriented parallel to the main magnetic field in order to maximize phase signal.

Imaging was conducted on a 1.5T Siemens Espree scanner using a sr-GRE sequence with 330ms effective inversion time. Hence, the sequence was optimized for T₁ down to about 150ms, which roughly corresponds to the minimum T₁ observed in a tumor after a standard injection (0.1 mmol/kg) of Magnevist or equivalents. Other sequence settings were, T_R/T_E = 6.7/3.95ms, data matrix 128 x 96, and FOV 25x25cm. To reduce flow induced phase changes the sequence was flow compensated and gated. One image was collected every 15s and the time to acquire an image was 650ms. The phase information was converted into contrast concentration with methods developed by Akbudak et al. [2]. Magnitude data were analyzed with both signal equations and a calibration curve which was estimated from 15 points on the signal enhancement curve and the true concentration curve. All points were from the non-saturated part of the enhancement curve. Using this calibration curve, the quality of the derived concentrations from the magnitude data is as good as or better than what would be obtained under normal experimental conditions.

Results

Figure 1 shows the results from both magnitude and phase data. Magnitude data analyzed with signal equations are not shown since the results were off-scale with a large factor, likely due to not modeled in- and outflow effects. It is clear from the figure that magnitude data can only be used for low concentration while the phase offers both high precision and good linearity over the full tested range. The accuracy of the (green) curve derived from phase data was good but not perfect (6% underestimation). The red curve is a scaled version of the green and shows that the underestimation was consistent over the entire range and hence that the linearity was good.

Discussion

The results from the flow phantom measurements indicates that phase information from a sr-GRE sequence with inversion time optimized for tissue T₁ is well suited for determination of the AIF and is superior to what can be obtained from the magnitude data alone. Both precision and linearity were good while the accuracy needs to be investigated further. The 6% underestimation can at least partially be explained by uncertainties in the experimental setup but is more likely to have been caused by image artifacts.

References

- [1] Ivancevic MK, et al. Magn Reson Med. 2003 Nov; 50(5):885-91.
- [2] Akbudak E, Conturo TE. Magn Reson Med. 1996 Dec; 36(6):809-15.
- [3] Van Osch, et al. J Magn Reson Imaging. 2005 Dec; 22(6):704-9.

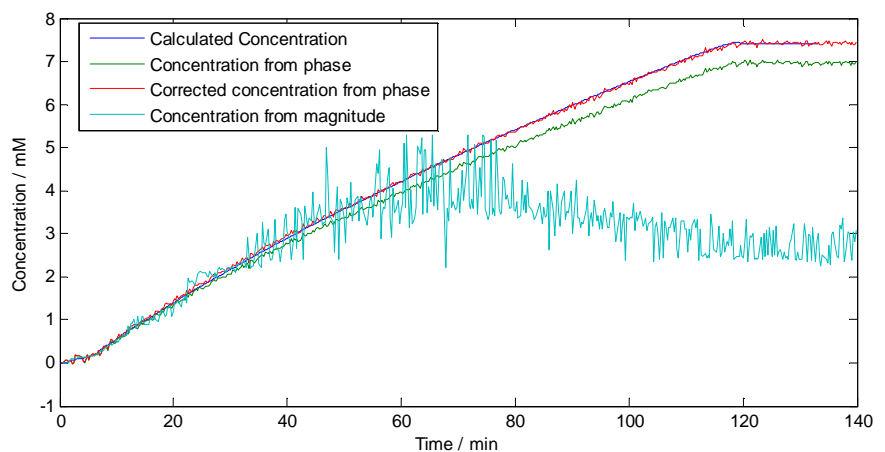


Figure 1. Estimated and measured concentration from phase and magnitude data.