Studies of Gd-DTPA Relaxivity in different tissue models at 3T

C-Y. Liu[1], P. Varadarajan[2], G. M. Pohost[2], K. S. Nayak[1]

[1]Electrical Engineering, University of Southern California, Los Angeles, CA, United States, [2]Cardiovascular Medicine, University of Southern California, Los Angeles, CA, United States

Introduction

Quantification of myocardial perfusion is important for the evaluation of myocardial ischemic and infarct It is essential to be able to infer regional contrast concentration from imaging data such as signal intensity, which is a function of T1 relaxation time and pulse sequence parameters. T1 relaxivity of MR contrast agents at lower field strength have been reported [1]. The object of this work was to study the relaxivity of Gd-DTPA in slow and fast water exchange environments using 3T MRI in phantoms. Measurements at 1.5T were also performed for comparison.

Methods

Two types of baseline solutions were prepared. A mixture of de-ionized water with Gd-DTPA (Magnevist, Berlex Laboratories, Wayne, NJ) was produced as a baseline to mimic normal myocardial T1. Twenty-one tubes with Gd-DTPA in this baseline solution were filled at various concentrations (from 0.005 to 4 mmol/L). Another set of twelve tubes were prepared using human serum albumin (HSA, 25%) as baseline solutions doped with an equivalent range of Gd-DTPA. T1 measurements were carried out using an inversion-recovery fast spin echo (IR-FSE) sequence with a variable preparation time TI on a GE Excite 3T scanner. Regions of interest were drawn inside the tubes; the signal intensities (*S*) normalized to the fully relaxed signal intensities (*So*) were plotted as a function of TI (data not shown). T1 values were calculated from the slope of TI at null point by fitting a line through at least three negative and positive image intensities. Separate measurements of signal intensity using IR-FSE with *TR=1000ms*, *TI=400ms* were performed to establish the relationship between the predicted signal response and 1/T1. This protocol was designed to null the normal myocardium at 3T for a heart rate of 60 bpm. Only the water baseline samples were imaged on GE Excite 1.5T system with IR-FSE sequence of the same protocol.

Results

Figure 1 compares the experimental and simulated data of IR-FSE sequence of the same protocol. Both solutions show consistent results with the theoretical prediction. A summary of the relationship between 1/T1 and the concentration (*C*) of Gd-DTPA obtained from two baseline solutions at 3T is shown in Figure 2. The relaxivity (*r*) is defined as $1/T1=1/T1_o+rC$ [2]. The baselines (*T1=1080*ms for water and *947*ms for HSA) are displayed as zero concentration. Signal intensity saturated above *2.0* and *1.12* mmol/L at water and HSA baselines respectively (not shown in the fittings). The slopes of linear fits to both data gave relaxivities for Gd-DTPA in water of *4.94±0.83* and *8.9±0.50* ($mmol^{-1}*sec^{-1}$) in HSA at 3T. For the comparison result at 1.5T (not shown), T1 of the water baseline solutions is *1082*ms with relaxivity of *5.05±0.75* ($mmol^{-1}*sec^{-1}$). The result at 1.5T of the baseline samples in water was not significantly differs from 3T. Our measurement of relaxivity in water is higher than the literature value (4.5 [1]) at 1.5T.

Discussion

The present study demonstrates the extracellular agent Gd-DTPA changes its relaxivity from approximately 8.9 to 4.9 ($mmol^{-1}*sec^{-1}$) depending on tissue environments (albumin or water). It is known [2] that the rate of water exchange plays an important role in determining the contrast agent's relaxivity. The longer the correlation time, the slower the water exchange rate. One way to increase the relaxivity is to increase the correlation time, which is the average time that the bond water stays coordinated to Gd. This is often observed in strong albumin-binding compounds such as blood pool agents. Gd-DTPA does not usually belong to this category. However, its relaxivity is significantly increased (80% higher in 25% HSA compared to in water) in extreme settings. The assumption of identical relaxivity in-vitro and in-vivo may lead to substantial systematic errors of Gd concentration quantification.

References

[1] Stanisz,G. *et al*., MRM, 44:665:667, 2000

[2] Weisskoff, R and Caravan, P, Cardiovascular Magnetic Resonance: Established and Emerging Applications, Chapter 2: MR contrast agent basics, Taylor and Francis Group, Feb, 1, 2004.

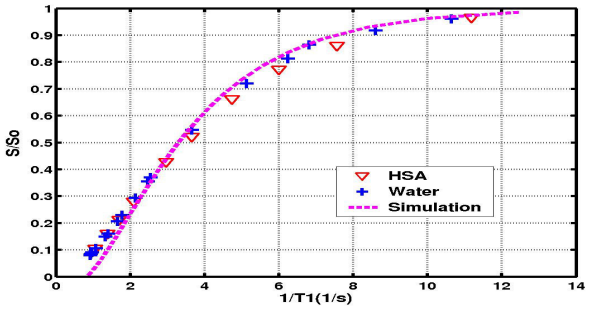

Figure 1. Experimental and simulated (IR-FSE sequence) relationships between signal intensity normalized to fully relaxed magnetization (S/So) and 1/T1 for both solution sets at 3T. The simulated curve agrees well with the phantom studies.

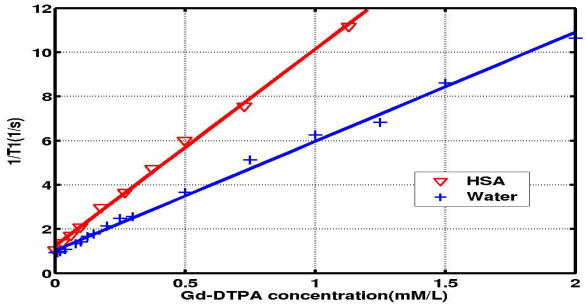

Figure 2. Linear relationship between 1/T1 and Gd-DTPA concentration for different environments at 3T. Relaxivity (the slope of the linear fit) is 80% higher in HSA than in water.