Effect of Contrast Media on the Signal Intensity of Single-Shot EPI for Diffusion Imaging of the Body

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Introduction

Diffusion weighted imaging (DWI), while a long established technique for evaluation of the neurological system, is relatively new and unproven in body imaging. Whether to acquire diffusion weighted images before or after contrast, therefore remains an open question. There are published studies in the literature stating that the signal intensity (SI) and measured ADC in the brain are not affected by administration of contrast (1-3), and that the same is true in the liver (4). Our experience, however, had been the contrary – DWI of the body obtained for clinical purposes appeared to be of higher quality when obtained before contrast, rather than after contrast. We hypothesized that T_2 shortening provided by circulating contrast media significantly decreased the signal to noise ratio (SNR) in the heavily T_2-weighted, single shot EPI images, thereby leading to the observed image degradation. This hypothesis was tested with theoretical calculations, and simple experiments on a phantom and a human volunteer.

Materials and Methods

The expected behavior of SI in a saturation recovery experiment in the presence of various concentrations of contrast agent was modeled, simply by the well accepted relationships (4): $R_1(C) = 1/T_{1,0} + \alpha_1 C$ and $R_2(C) = 1/T_{2,0} + \alpha_2 C$, where C is the concentration, $T_{1,0}$ and $T_{2,0}$ are the intrinsic T_1 and T_2 values with no contrast agent and are obtained from the literature (6), and α_1 and α_2 were obtained experimentally from measurements on gadolinium solutions. Expected signal versus concentration curves for water as well as liver and renal parenchyma were generated from simple Bloch equations (assuming TR/TE of 2400/70 ms). The predicted behavior for water was tested on spin echo EPI on a phantom with gadolinium solutions of various concentrations (Siemens Espree Spectrometer, 12 channel body array coil, ssSE-EPI, TR/TE= 2400/71 ms, GRAPPA factor 2, 38 cm FOV, 150x150 MX, 5 mm slice thickness). An asymptomatic volunteer was adminstered contrast (Optimark, 0.1 mmol/mL, 15 mL), and serial ssSE-EPI images were obtained (TR/TE 2800/79 ms , 36 cm FOV, 162x162 MX, 7 mm slice thickness, b=0 & 500 s/mm^2). SI was measured in ROIs in the renal cortex and medulla, liver, pancreas, and spleen.

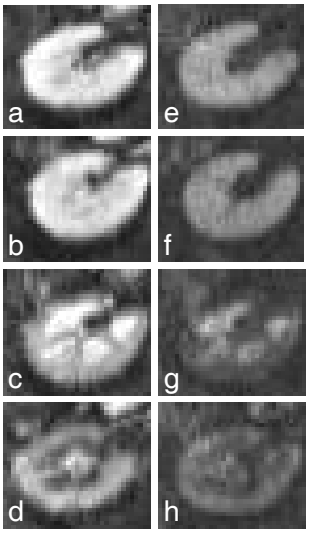

Figure 3: Single shot EPI images cropped to show the right kidney with b=0 (a-d) and b=500 s/mm^2 (e-h), at times 0 (a,e), 1 min (b,f), 2 min (c,g), and 5 min (d,h) post contrast administration.

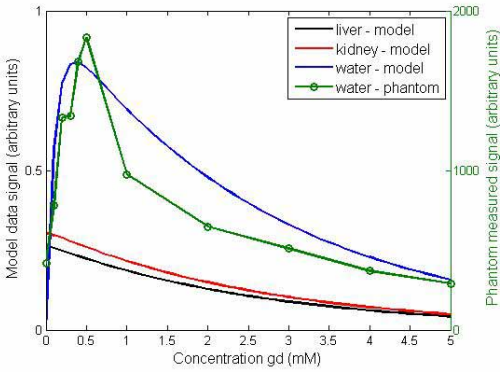

Figure 1: Model data for expected signal behavior of water, liver, and kidney (blue, black, red) at various contrast concentrations, and measured data for a water phantom (green)

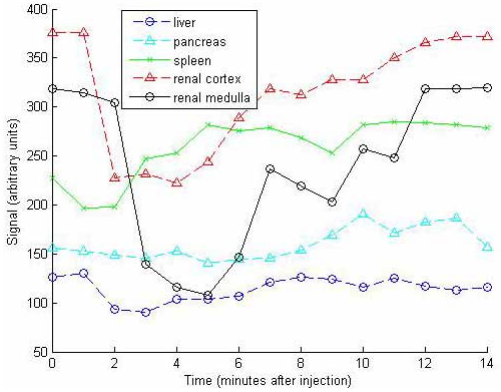

Figure 2: Volunteer study. Signal intensity versus time after contrast injection for renal cortex and medulla, liver, pancreas and spleen.

Results and Discussion

The predicted SIs for a simple spin-echo experiment for water, and liver/renal parenchyma in the presence of various gadolinium concentrations are shown in Figure 1, in blue, black, and red, respectively. As can be seen, for very low gadolinium concentrations, water signal intensity is expected to increase, and then decrease as concentration increases. The parenchymal SIs for liver and kidney, on the other hand, are expected to always decrease with concentration. The measured phantom data (green) generally follow the predicted trend. The volunteer data show a marked drop in signal in the renal cortex/medulla and in the liver shortly after injection (see Figures 2 and 3), with signal returning to baseline after several minutes. There is actually a reversal of cortex/medulla contrast in the kidney, roughly 2 minutes after injection. The results show a large change in signal characteristics after injection of contrast in the liver and kidney, where signal losses of 30-60% are observed up to approximately 5 minutes after injection, with a gradual return to baseline thereafter. The results for these organs clearly indicate that if images are obtained after contrast injection, there would be loss of valuable signal, a key problem for an already SNR starved technique such as DWI. Moreover, since dynamic contrast enhanced images are typically obtained at 20, 70, and 180 seconds after contrast, if the DWI was to be performed post contrast, images would be most likely obtained 4-6 minutes after injection, the signal ebb for the kidneys, and still at a time where liver signal is low. This means that the DWI would be performed at the most sub-optimal time if the organ of interest is the kidney or liver. The pancreas signal shows little dependence on contrast until late, while T_1 shortening effects of the contrast agent appear to dominate in the spleen, where there is actually a net signal gain in the EPI images due to contrast. The observed behavior and the difference from the reported literature for the brain could be related to concentration of contrast in particularly the kidney, and the lack of a blood brain barrier in the abdomen. Difference from the literature on liver most likely relates to difference in T_1 weighting (4). Overall, experiments and simulations show that in planning whether to place the diffusion sequences before or after contrast, the effect of the contrast on the EPI signal intensity should be taken into account, and if the liver or kidneys are the organ of interest, the DWI should be performed before contrast.

References

1. Yamada et al, *Stroke* 2002;33:1799-1802. 2. Fitzek et al, *Neuroradiology* 2003;45:592-7. 3. Chen et al, *MRI* 2005;23:685-9. 4. Chiu et al, *JCAT* 2005;29:176-80. (5) Haacke et al, *Magnetic Resonance Imaging*, 1999, Wiley & Sons. (6) Stanisz et al, *MRM* 2005;54:507-12.