

Introduction

The ability to detect small differences in susceptibility is of great importance in MRI. Such a situation is especially important in the detection of early tumors where the accelerated growth of new blood vessels can shift the local resonance by only a few Hz. The use of non-linear feedback fields has been shown to be sensitive to small shifts in resonance offset and can be used to generate contrast which is typically invisible to relaxation-based contrast mechanisms [1]. Two well-known feedback fields include the distant dipolar field (DDF), and the radiation damping field. Radiation damping is a macroscopic coupling between the receiver coil and the total transverse magnetization. The macroscopic nature of radiation damping serves to indirectly couple each spin component with all other spins in the sample. We show that the application of continuous wave (CW) irradiation in the presence of the radiation damping feedback field produces unique fixed points on opposite poles of the Bloch sphere (Fig. 1) and can be used to generate contrast between early tumors and the surrounding healthy tissue, which is not so obvious from conventional imaging methods. We demonstrate the feasibility of applying these dynamics to medical practice with the successful detection of early tumors on 7 different mice.

Theory and Methods

The radiation damping feedback field depends explicitly on the total transverse magnetization. As a result, the radiation damping field is negligible at any clinical field strength and cannot be exploited without the aid of an active feedback device. Such an active feedback circuit reads the instantaneous free induction decay (FID) and retransmits the signal back onto the sample, essentially creating the effects of radiation damping without requiring higher magnetic field strengths. Application of a CW allows for the sample to continuously evolve under the non-linear feedback field, eventually leading to unexpected fixed points.

7 different mice with early-stage tumors were imaged with conventional imaging methods as well as with a CW in the presence of radiation damping, using a micro-imaging setup on a 300MHz NMR spectrometer. Tumors cells from the Caucasian colon adenocarcinoma were implanted into the right legs of each mouse prior to imaging.

Results

Figure 2 shows a comparison of different imaging methods and their performance at picking out an early stage tumor. Figure 2A is a proton density image, where the white box indicates the region highlighted in Figs. 2B-G. Both the T_1 and T_2 -weighted images faintly show the location of the tumor, whereas the T_2^* -weighted image shows little evidence of a tumor. The susceptibility-weighted image (Fig. 2E), being dependent on the T_2^* -weighted image, struggles to determine the location of the tumor. Lastly, an image taken with a CW in the presence of the feedback (Fig. 2F) highlights the presence of the tumor much more efficiently than the relaxation-based methods where the contrast is very faint. The pathology reports confirm the presence of tumor cells and accurately matches the dimensions shown in the imaging. The average calculated contrast-to-noise ratios (CNR) for the other mice can be seen in Fig. 3, where it can be seen that the use of a CW in the presence of radiation damping gives a consistently better CNR over all other conventional methods.

Discussion

Conclusions - The use of a CW in the presence of strong radiation damping can be seen to produce unique contrast enhancement, and can be a useful supplement to conventional methods in the detection of tissues with small susceptibility variations, such as tumors.

References - [1] S. Y. Huang et al., MRM 56, 776 (2006).

7187

In Vivo Tumor Detection and Characterization by Fixed-Point Imagin

J. Furuyama¹, D. W. Hwang¹, and Y-Y. Lin¹

¹Chemistry and Biochemistry, UCLA, Los Angeles, CA, Uni

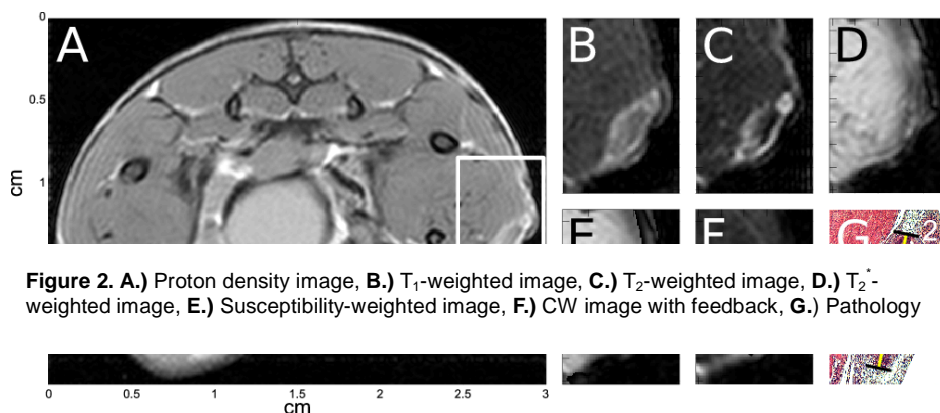


Figure 2. A.) Proton density image, B.) T_1 -weighted image, C.) T_2 -weighted image, D.) T_2^* -weighted image, E.) Susceptibility-weighted image, F.) CW image with feedback, G.) Pathology

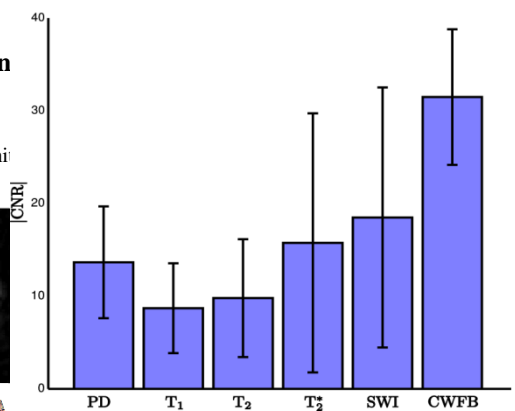


Figure 3. Average contrast-to-noise ratios (CNR) for 7 different mice. Error bars are standard deviations.