

A new MRI method for monitoring thermal coagulation

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Introduction

An image with a good contrast between coagulated and non-coagulated tissue can assist in improving the accuracy and the reliability of thermal ablation of tumors and of uterine fibroids. As was recently reported (1), the rate of magnetization exchange between macromolecules and water in the tissue depends on the degree of coagulation of the tissue. Here we report the application of this finding in the form of a new MRI method for following the degree of thermal coagulation. The method was tested for porcine liver and muscle.

Methods

Figure 1 illustrates the magnetization exchange imaging sequence (MEXI). The result of the first two pulses is the elimination of the protein magnetization, leaving only the longitudinal magnetization of water. During t_{zq} magnetization exchange occurs between water and the protein. Starting with the slice selective pulse any MRI sequence can be used. A gradient echo method is given in Figure 1. The obtained image is weighted by magnetization exchange. When the applied pulses are very short, the optimal duration of the interval τ is about 400 μ s in which there is a complete decay of protein magnetization. However, for clinical scanners, where short pulses are not feasible, the protein relaxation occurs during the long pulses. It was found that the signal could be maximized for an angle of rotation (ϕ in figure 1) larger than 90° for the first two pulses. For pulses of 200 μ s the pulses used

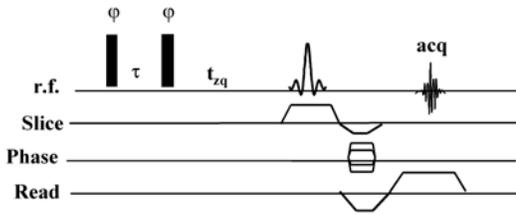


Figure 1: The MEXI pulse sequence.

were in the range 180°-270°, with $\tau = 20\mu$ s. The sequence is repeated twice with two values of t_{zq} . One value long enough for magnetization exchange to occur and a second value in which there is no magnetization exchange. The two values were 40ms and 10 μ s respectively in the examples shown in figures 2b and 2d. The two images are subtracted from each other, resulting in an image, which shows a signal resulting only from magnetization exchange between water and macromolecules.

Results

Samples containing two layers of porcine liver or of porcine muscle were prepared. At the bottom of the tube a layer of the tissue after immersion in hot water (65°C) for 15 minutes, separated by a thin Teflon disk from the upper layer of non-treated fresh tissue. The samples were immersed in Fluorinated oil in order to improve homogeneity.

Images taken with the MEXI method are presented in plots b and d in figure 2. In plots a and c on the same figure, which were obtained with a conventional gradient echo, the two layers of liver and muscle respectively are observed. In plots b and d only the treated tissue (65°C for 15 minutes) is observed.

Discussion

An imaging method, which shows directly the result of a thermal treatment, could improve enormously the quality of the treatment. As the magnetization exchange time was found to be insensitive to temperature (1), the MEXI method can be used throughout the treatment, without effects of temperature fluctuations. Another important advantage is the absence of a contrast agent.

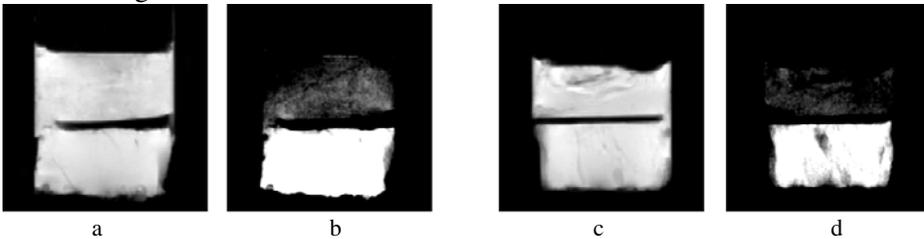


Figure 2: A tube containing two layers of liver (the same sample at plots a and b) or muscle (the same sample at plots c and d). Lower layer is after immersion for 15 minutes in 65°C. Upper layer is of non-treated tissue. Plots a and c: conventional Gradient Echo. Plots b and d: MEXI. FOV: 13x13mm. Matrix 128X128, TE=2.14ms. Slice thickness: Plots a and b:1.7mm. Plots b and d: 2mm. TR: a. 2000ms, b. 500ms, c. 1000ms, d. 800ms. NEX: a and c:1. b and d: 16.

References

1. D. Carasso, U. Eliav, G. Navon. Nuclear Magnetic Resonance Parameters for Monitoring Coagulation of Liver Tissue. Magn Reson Med 2005;54:1082-1086.