T2 Contrast in the FRFSE Sequence: Application to Liver Lesions

Erik K. Insok MD, PhD and Leon Axel MD, PhD
*Hospital of the University of Pennsylvania, Department of Radiology, Philadelphia, PA
#NYU School of Medicine, New York, NY

ABSTRACT:
The contrast of the fast-recovery fast-spin-echo (FRFSE) sequence is analyzed by theory, phantom experiments and region-of-interest (ROI) analysis of in-vivo data. The signal in the liver and spleen as well as liver lesion contrast is compared to that of the conventional respiratory triggered fast-spin-echo (RT-FSE). The results prove that intermediate T2 lesions within the liver have lower contrast-to-noise ratios in the FRFSE sequence. Such lesions may include metastases, primary tumors and abscesses.

INTRODUCTION:
The FRFSE pulse sequence has been touted as a replacement for the standard RT-FSE. FRFSE differs from FSE by the addition of two radiofrequency (RF) pulses after the last data acquisition. First a 180° pulse is applied, and when the residual transverse magnetization is refocused, a 90° pulse is applied to drive the magnetization back to the longitudinal axis. This is a driven equilibrium (DEFT) method. By recovering the residual magnetization, the signal-to-noise ratio (SNR) may be improved. However, the most important aspect of lesion detection is contrast-to-noise ratio (CNR).

The contrast in images obtained with FRFSE is a combination of T1 and T2 effects. The results of theory, phantom images and in-vivo data will show the CNR of intermediate T2 species such as liver metastases is lower in FRFSE compared with FSE images.

METHODS:

Theory: The signal in an image is proportional to the steady state magnetization. With FSE the signal is proportional to

\[ \text{signal}_{\text{FSE}} = \left[ 1 - e^{-\frac{T_2}{T_1}} \right] e^{-\frac{T_1}{T_2}} \quad [1] \]

where \( T_d \) is the time between the last echo and the next excitation pulse. \( T_d \) is defined by the echo train length (ET), echo spacing (esp) and repetition time (TR) as \( T_d = TR-ET*\text{esp} \).

With FRFSE the signal is proportional to

\[ \text{signal}_{\text{FRFSE}} = \left[ 1 - e^{-\frac{T_2}{T_1}} \right] \left( 1 - e^{-\frac{TE}{T_1}} \right) e^{-\frac{TE}{T_2}} \quad [2] \]

where \( T_d \) is the time just prior to the DEFT pulse (defined by \( ET*\text{esp} \)). Equations [1] and [2] were used to model signal characteristics expected for various imaging and relaxation times.

Phantom Imaging: Phantoms containing solutions of Gd-DTPA, BSA and MnCl₂ were produced. The relaxation times were determined by multiple spin-echo and progressive saturation methods. Solute concentrations were adjusted to approximate tissue relaxation times (2). The phantoms were imaged with FRFSE and FSE on a 1.5 T system (Signa, GE Medical Systems, Milwaukce, WI) (Td=2.36, TR=2.5s).

In-Vivo Data: ROI analysis was performed on in-vivo data to determine the liver-spleen and liver-metastases contrast in FRFSE and RT-FSE images. Lesions with the same signal as spleen are often metastases (2) and thus spleen is a useful internal contrast reference.

RESULTS:
The functions in equations [1] and [2] are plotted below for various tissue characteristics and pulse sequence parameters. Signal enhancement only occurs when the DEFT pulse is applied at a time that is less than the T2 of the tissue. For the pulse sequences utilized the DEFT pulse is applied after 138 ms. Only tissues with T2’s longer than 138 ms will be signal enhanced.

Moreover, the DEFT pulse enhancement is only significant for tissues where the longitudinal relaxation time is long. Theory predicts that the DEFT pulse should enhance the signal of long T1, long T2 tissues (cyst, hemangioma). Intermediate T2 species (tumor, abscess) will have minimal enhancement which decreases their conspicuous. In addition, the shorter T1 of liver compared with metastases will decrease liver-lesion contrast.

The phantom and in-vivo data demonstrate the reduced DEFT enhancement and lesion contrast for intermediate T2 species.

CONCLUSIONS:
FRFSE images have decreased CNR compared to FSE (3,4). We confirm this result for in-vivo imaging and demonstrate its origin with both theoretical arguments and phantom experiments. The use of the DEFT pulse results in images which are primarily T2 weighted only for typically benign lesions (e.g., cysts, hemangiomas) but have mixed T1 and T2 contrast for many significant lesions (e.g., 1° tumors, mets, abscesses), which are therefore less conspicuous on FRFSE images.

DEFT ENHANCEMENT

The bold lines are the predicted signal for FRFSE and the nonbold are the predicted signal for FSE. The solid line represents the long T1 species (greatest enhancement), the dotted line the intermediate species and the dashed line the short T1 species (least enhancement). The Td (defined as the time of the last data acquisition) used in the clinical exams was 138 ms.

REFERENCES: