Fat Suppression Techniques – a Short Overview

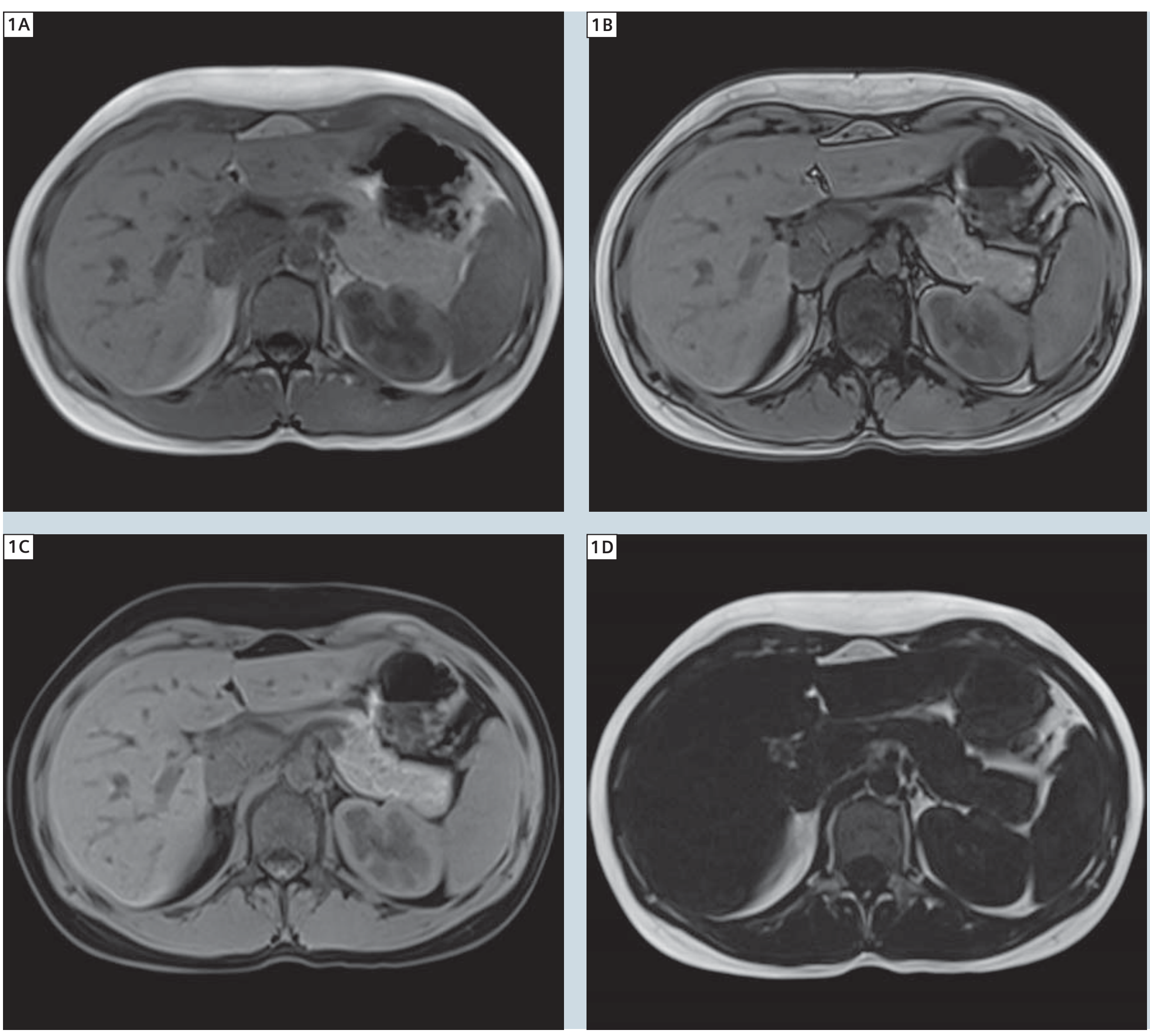
Wilhelm Horger; Berthold Kiefer

Siemens Healthcare, Erlangen, Germany

Introduction and background

Fat-suppression is an integral part of nearly any routine MR application. Insufficient elimination of the fat signal or even saturation of tissue of interest in an MR image can have severe consequences and therefore the knowledge about available fat-suppression techniques and their individual advantages and disadvantages are required. The purpose of this article is to provide a short technical overview of the main fat-suppression techniques available for clinical routine.

All techniques for fat suppression are based on the fact that – due to the different chemical environment – hydrogen nuclei in water and in fat-tissue have different values for some MRI-relevant parameters, mainly the relaxation time and the resonance frequency



1 Dixon technique (VIBE). Four contrasts generated in one breathhold:
1A: in-phase
1B: opposed-phase
1C: water image
1D: fat image

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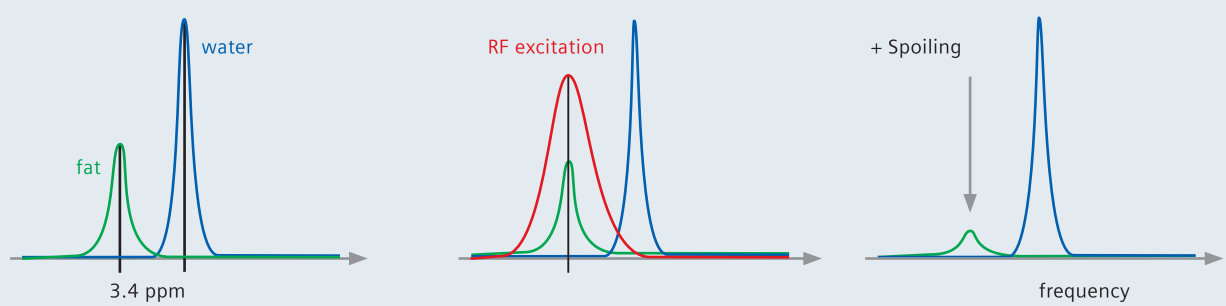

2 Spectral fat saturation.

(chemical shift). These differences can be used to selectively suppress or reduce the signal of fat bound protons. Thus one can differentiate between two types of fat-suppression techniques:

a) Relaxation-dependant (e.g. STIR)

b) Chemical shift-dependant methods (e.g. Dixon technique (available for VIBE and TSE sequence techniques), spectral fat saturation, water excitation and SPAIR).

Dixon technique

The Dixon technique is based on the chemical shift i.e. the difference in resonance frequencies between fat and water-bound protons. With this technique two images are acquired. In the first image the signal from fat-protons and from water-protons are 'in phase'; in the second they are 'opposed phase'. A separate fat and water-image can then be calculated. The Dixon method is integrated into the VIBE sequence and TSE sequence (compare Fig. 1).
Dixon delivers up to 4 contrasts in one measurement: in-phase, opposed-phase, water and fat images.

Advantages of the Dixon technique:

- Insensitive to B_0 and B_1 inhomogeneities.
- 4 contrasts delivered in one measurement.

Disadvantage of the Dixon technique:

- Increases minimal TR because in- and opposed phase data must be acquired. This can be compensated by using integrated Parallel Acquisition Techniques (iPAT).

Spectral fat saturation

This technique is based on the chemical shift (3.4 ppm) i.e. the difference in resonance frequencies between fat- and water-bound protons. The application of a narrow band frequency selective radiofrequency (RF) pulse excites mainly fat-bound protons. This transversal magnetization is destroyed afterwards by spoiler gradients, thus no fat magnetization is left for imaging (compare figure 2).
For spectral fat saturation, a 'Quick-Fat-Sat' setting is available. If this feature is selected, not every slice excitation is preceded by a preparation pulse. This means:

- Shorter possible TR;
- Shorter breath-hold examinations (e.g. VIBE, recommended 40 lines/shot).

Two FatSat modes (strong/weak) are also available. Basically, the user can select how much of the fat signal is contributing to the MR image. In the 'strong' mode a nearly full suppression is achieved, whereas in the 'weak' modus, anatomical information of fatty tissue is partially preserved.

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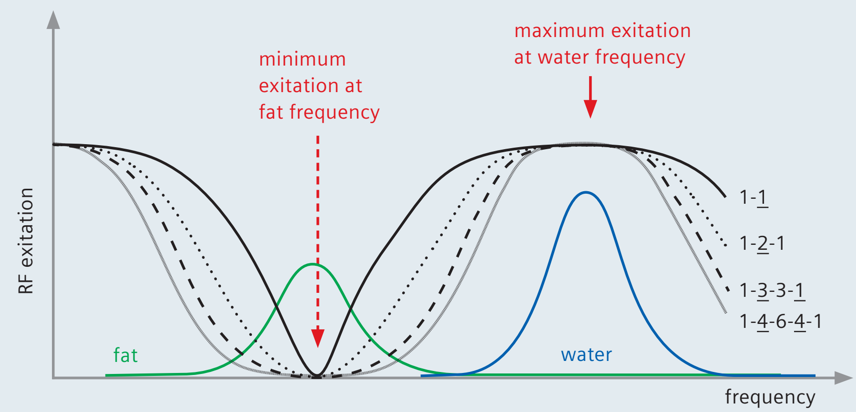

3 Water Excitation.

Advantages of spectral fat saturation:

- Tissue contrast is not affected;
- Quick-FatSat can be applied for increased performance.

Disadvantages of spectral fat saturation:

- Sensitive to B_0 and B_1 inhomogeneities;
- Additional preparation pulse increases minimal TR and total measurement time or reduces maximum number of slices (partially compensated by Quick-Fat Sat).

Water excitation

This technique is based on the chemical shift i.e. the difference in resonance frequencies between fat and water-bound protons. No additional preparation pulse is necessary. Instead, a special excitation pulse (binomial pulse) is used with the spectral excitation profile (minimum excitation of fat bound protons, maximum excitation of water-bound protons) (compare Fig. 3).

Advantages of water excitation:

- Reduced sensitivity to B_1 inhomogeneities.

Disadvantages of water excitation:

- Increased min TE, TR and total measurement time or reduced maximum number of slices.

Fat suppression with Inversion Recovery

In clinical routine, two types of inversion recovery techniques are applied: SPAIR (Spectrally Adiabatic Inversion Recovery) method, and Short TI Inversion Recovery (STIR; in principal identical to TIRM (Turbo Inversion Recovery Magnetization) technique).

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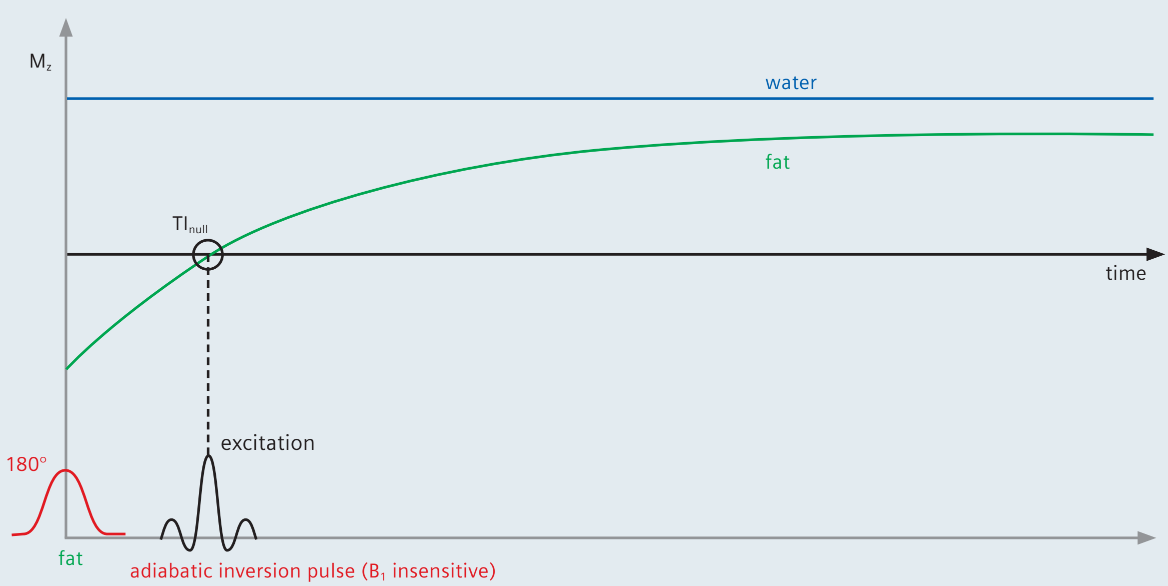

4 SPAIR technique.

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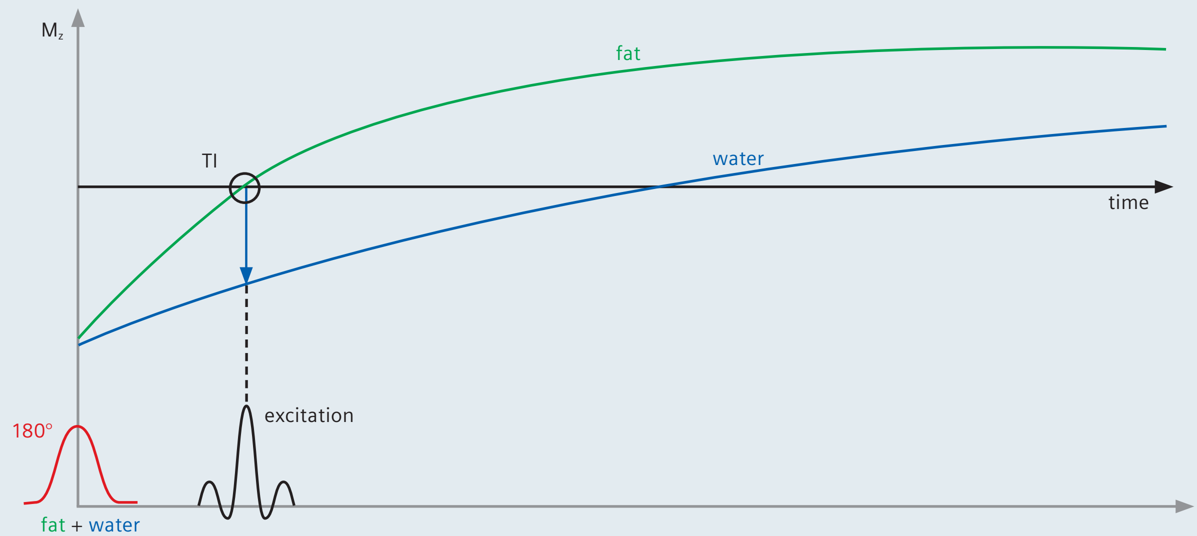

5 STIR technique.

SPAIR technique (Spectrally Adiabatic Inversion Recovery)

SPAIR is an alternative to the conventional spectral fat saturation. A spectrally selective adiabatic inversion pulse excites only fat spins, thus no STIR like contrast is created. With gradient spoiling the transverse magnetization is destroyed. The inversion time TI is such that the longitudinal magnetization of fat at the time when the excitation pulse is applied is zero, so fat spins will not contribute to the MR signal (compare Fig. 4).

Advantages of SPAIR:

- Insensitive to B_1 inhomogeneity;
- Tissue contrast is not affected.

Disadvantages of SPAIR:

- Increased minimal TR or reduced maximal number of slices due to more complex preparation pulse (partially compensated by Quick-Fat Sat).

STIR (Short TI Inversion Recovery)

This relaxation-dependant technique is based on the different relaxation behavior of water and fat tissue. Fat has a much shorter T1 relaxation time than other tissues. Prior to the excitation pulse of the sequence an inversion pulse (= 180°) is applied which inverts the spins of all tissue and fat protons. This is followed by T1 relaxation. When choosing TI such that the longitudinal magnetization of fat at the time when the excitation pulse is applied is zero, the fat spins will not contribute to the MR signal. STIR images have an inverted T1 contrast: Tissue with long T1 appears brighter than tissue with short T1 (compare Fig. 5).

Advantages of STIR:

- Insensitive to B_0 inhomogeneities.

Disadvantages of STIR:

- Additional inversion pulse increases minimal TR and total measurement time or reduces maximum number of slices;
- Tissue contrast is affected, SNR is reduced.

Contact
Wilhelm Horger
Siemens AG
H IM MR PLM-AW ONCO
Allee am Roethelheimpark 2
D-91052 Erlangen
Germany
wilhelm.horger@siemens.com

→ In this article, the Siemens nomenclature is used. A list of MRI acronyms for a variety of MR techniques and different vendors as well as a booklet with detailed description of MR terms can be found at our MAGNETOM World Internet site. Follow the QR code or visit us at **www.siemens.com/magnetom-world** and go to **MR Basics** under **Publications**.