Fat Suppression MRI Techniques

Marwa Fathy Mostafa Mohamed [(1)], **Hazim Ibrahim Tantawy** [(1)], **Ahmed Mohamed Alsowey** [(1)], **Shimaa Abdelmoneem Mohamed Ateya** [(2)], **Maha Ibrahim Metwaly** [(1)]
(1) Department of Radiodiagnosis, Faculty of Medicine, Zagazig University, Zagazig, Egypt.
(2) Clinical hematology unit, Department of Internal medicine, Faculty of Medicine, Zagazig University, Zagazig, Egypt.
Corresponding author: Marwa Fathy Mostafa Mohamed
E-mail: marwafathy45@gmail.com, mfkhalil@medicine.zu.edu.eg
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Abstract

Background: Fat suppression is a widely used technique in magnetic resonance imaging (MR) to eliminate the signal originating from adipose tissue. It applies to both T1W and T2W sequences. Suppression of fat can be accomplished in several ways. The goal of the fat suppression (contrast enhancement vs. tissue characterization), the quantity of fat in the tissue under study, the magnet's field intensity, and the homogeneity of the primary magnetic field should all be taken into consideration when choosing a procedure. This technique's main limitations are that it is not very reliable when employed with low-field-strength magnets, and it is sensitive to magnetic field inhomogeneity and misregistration artifacts. Inversion-recovery imaging enables both homogenous and global suppression of fat and can be used with low-field-strength magnets. However, this technique is not fat-specific, and there can be misunderstandings about the difference in signal intensity between tissue with a long T1 and tissue with a short T1. Opposed-phase imaging technology is rapid and simple to use. It is recommended to demonstrate lesions with traces of fat using this method. The main drawback of opposed-phase imaging is its inability to reliably detect small tumors embedded in adipose tissue.

Keywords: Fat suppression, inversion-recovery imaging, opposed-phase imaging

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Introduction:

Fat protons appear bright on T1 and T2 weighted images due to their short T1 and long T2 relaxation times, which dilutes the image's dynamic range and reduces the contrast between the relevant tissues. [(1)]. In regions where fat may cause difficulties with the interpretation of the MRI images, fat saturation is very helpful. The basic concept behind fat saturation is that, in contrast to other tissues in the body, fat has a specific resonance frequency. The fat signal can be selectively reduced while mostly sparing the signals from other tissues by administering a radiofrequency pulse at the resonance frequency of fat [2]. However, small amounts of lipids are more difficult to detect on conventional MRI. In addition, the high signal due to fat may be responsible for artifacts such as ghosting and chemical shift. The high signal can also mask subtle contrast differences in non-fatty tissue by filling the dynamic range of the receiver with mostly fat signal. Lastly, a contrast enhancing tumor may be hidden by the surrounding fat. These problems have prompted the development of fat suppression techniques in MRI [3]. Smaller lipid concentrations are more challenging to find with conventional MRI. In addition, artifacts like chemical shift and ghosting could be caused by the high signal resulting from fat. Because the high signal fills the receiver's dynamic range mostly with fat signal, it can also conceal slight contrast differences in non-fatty tissue. Lastly, the surrounding fat could hide a tumor-enhancing contrast. These issues have led to the development of MRI fat suppression methods [4]. Black stripe (India Ink artifact) may also appear at the fat-water interface on opposed-phase chemical shift MR image It indicates the presence of water and fat protons in the same voxel. It occurs between macroscopic fat and non-fat portions of the body. It might have an impact on how anatomical details are shown in the images [2,4,5]. Therefore, it is desirable to suppress fat in order to enhance image quality. There are different techniques for fat suppression in MR imaging as the following: Chemical shift-based fat suppression (chemical shift selective [CHESS], water excitation and Dixon), Inversion-based fat suppression (short tau inversion recovery [STIR] and Hybrid techniques (spectral attenuated inversion recovery [SPAIR] and spectral pre-saturation with inversion recovery) [6]. Radiologists can choose the fat-suppression method that best matches their clinical practice by being aware of the various options available [1].

1- Chemical Shift Selective (CHESS) fat saturation images (fat-sat, FS):

In Magnetic Resonance Imaging (MRI), chemical fat saturation is a technique that selectively suppresses the signal from fat protons but preserves the signal from other tissues. It is based on the fact that protons in fat and water have different resonance frequencies by nature. This method involves applying a selective radiofrequency (RF) pulse that focuses on the fat resonance frequency, saturating and dephasing the fat signal (Fig. 1). The remaining water protons then generate the required signal, resulting in the suppression of fat. CHESS is a flexible application that may be added to any pulse sequence [2].

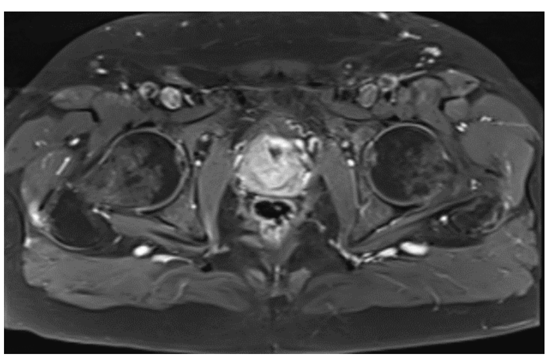

Figure (1): Shows axial T1 fat suppression (FS) with contrast on the pelvis.

Its advantages are: 1- Effective fat suppression: This method makes other tissues or structures of interest more visible by significantly reducing or eliminating the fat signal. 2- better tissue characterization: Chemical fat saturation improves tissue characterization and diagnostic precision by selectively reducing the fat signal, making it easier to distinguish between fat and other tissues.3-Compatibility with several imaging sequences: Chemical fat saturation can be applied to T1W or T2W imaging sequences, providing flexibility in image acquisition [7,8].

Its disadvantages are: 1- Sensitivity to magnetic field inhomogeneities: Incomplete fat saturation may arise from differences in the magnetic field inside patients or between various parts of the body. Inconsistent fat suppression or residual fat signal may result from this. 2-Differences in the composition of fat: The resonant frequencies of various fat types differ slightly. Since the RF pulse might not precisely match the resonant frequency of every fat proton, this could have an impact on the precision and consistency of fat saturation measurements. 3-Possibility of artifacts: Motion artifacts, such as breathing or patient movement, can bring artifacts into images and impact the effectiveness of fat suppression [7,8].

2- Water excitation:

This technique is also based on the chemical shift. The fat signal is suppressed while the water signal is selectively excited using the water excitation approach. A particular excitation RF pulse (binomial pulse) is applied, which stimulates the protons in water and suppresses the protons in fat. When imaging structures with a high fat content, such the breast or abdomen, this technique is used especially.

Its advantages are ■ reduced sensitivity to B1 inhomogeneities. ■ It provides strong fat suppression, so enhancement of contrast in the image and makes it easier to see other relevant tissues or structures. ■ Enhancement of tissue characterization ■ It can improve blood vessel visibility in angiography and vascular imaging by attenuating the signal from surrounding fat tissues [9] .

Its disadvantages are Increased min TE, TR and total measurement time or reduced maximum number of slices [9].

3-Dixon technique:

Another method based on the chemical shift differential between water and fat protons in MRI is Dixon fat saturation [10]. In contrast to previous fat suppression features, the Dixon technique provides maps of the distribution of water and fat, and it permits the suppression of the fat signal during post-processing instead of during acquisition. Dixon imaging involves acquiring several images at various echo times (TEs). Dixon's techniques yielded four different imaging sets: fat-only (FO), water-only (WO), out-of-phase (OP), and in-phase (IP) images Fig 2 [11].

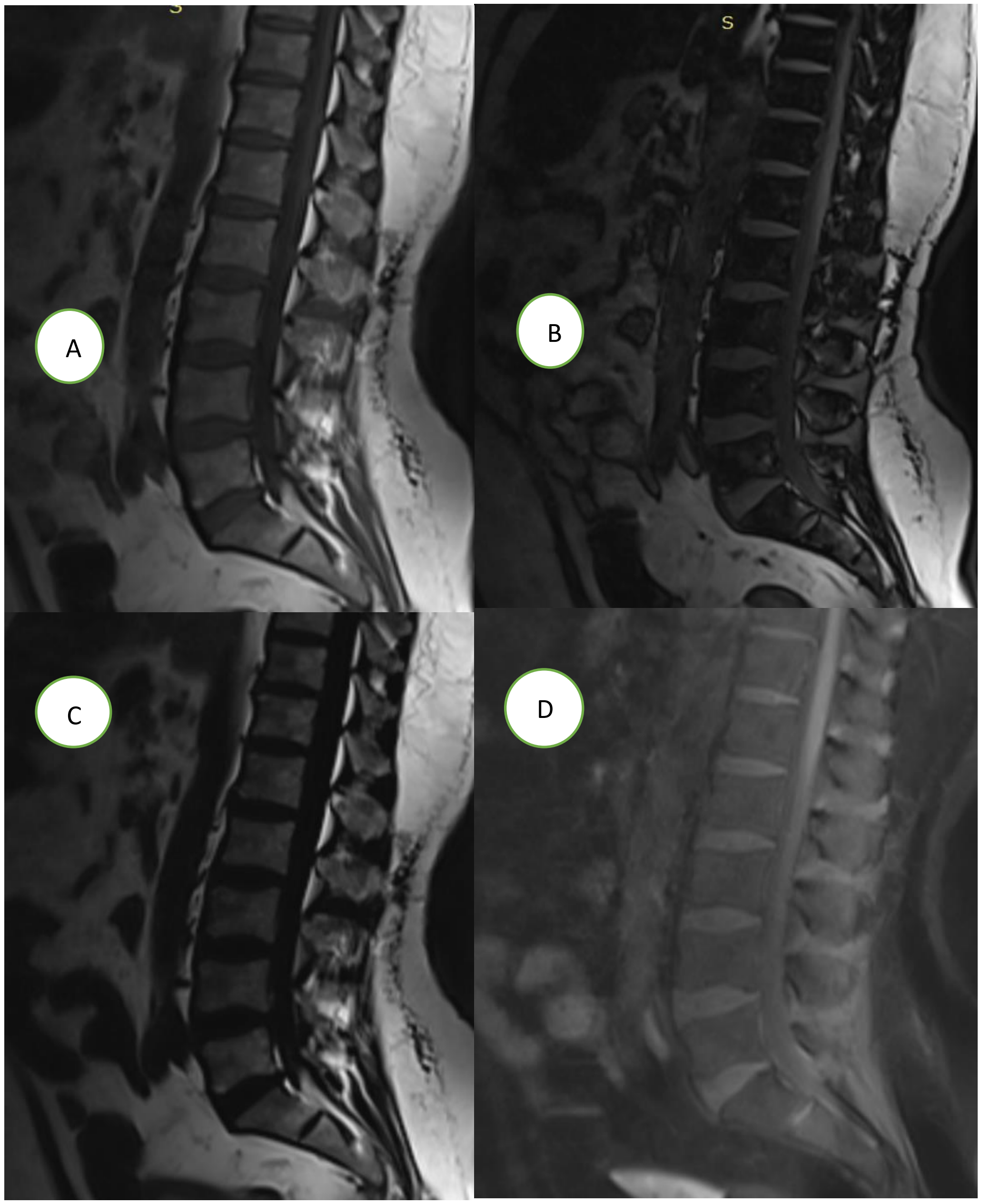

Fig 2: shows Dixon four images: A) in-phase image, B) out-off-phase image, C)fat-only image and D) water-only images.

Its advantages are: ■ Not affected by the inhomogeneities of B0 and B1.■ Since the fat signal can be extracted from the collected data to provide fat-only images, the Dixon technique allows robust fat suppression. This improves the contrast of the image and makes other tissues or structures easier to visualize. ■ The Dixon technique produces different fat-only and water-only images which improves tissue characterization [9, 11]. It can be used to quantify signal drop between in-phase and out-of-phase images or map the fat fraction [12,13].

Its disadvantages are■ Motion artifacts, such as respiratory or patient movement, can generate phase abnormalities in the recorded data, making the Dixon approach susceptible to them. In order to reduce these effects, motion correction techniques are frequently used. ■ In time-sensitive or patient-dependent imaging circumstances, the acquisition of numerous pictures with various echo times can result in a prolongation of the whole scan time [10,11].

4- STIR (Short Tau Inversion Recovery):

To improve image contrast and the visibility of other tissues, the fat saturation technique known as STIR (Short Tau Inversion Recovery) (Fig. 3) is employed in MRI to specifically null the signal from fat protons. STIR is built on the principle of inversion recovery, where a non-selective inversion pulse with a short inversion time (TI) is applied [14].

Fig 3: shows coronal STIR image on both hip joints and proximal femora.

T1 relaxation time is significantly shorter in fat than in other tissues. The TI in the STIR approach is adjusted to correspond with the fat's T1 relaxation time, which is normally between 150 and 200 msec. Fat protons' magnetization is reversed when the inversion pulse (= 180°) is applied, temporarily aligning them in opposite direction to the external magnetic field. Then, the fat signal is suppressed during the acquisition of the image, but the signal from the other tissues is retained. Fat signal suppression improves the visibility of the body's structures and pathologies. T1 contrast is reversed in STIR images: Compared to tissue with a short T1, tissue with a long T1 appears brighter. For whole-body imaging, STIR is frequently utilized as it offers uniform fat suppression [14].

Its advantages are: ■ It contributes to maintaining uniform fat saturation, which enhances image quality and improves diagnostic precision. ■ STIR increases tissue contrast by eliminating the signal from fat, which makes it simpler to identify anomalies or structures of interest [14,15,16].

Its disadvantages are ■ Sensitivity to the choice of inversion time (TI): Choosing a suitable TI that corresponds to the T1 relaxation time for fat is essential to the efficacy of STIR. Incomplete fat suppression or unwanted suppression of other tissues could happen if the TI is not set precisely. ■ Sensitivity to magnetic field inhomogeneities: Differences in the magnetic field between body parts or between individuals may have an impact on the accuracy of fat saturation, which may result in suboptimal fat suppression[14,15,16].

5-Spectral Attenuated Inversion Recovery (SPAIR)

In order to preserve the signal from other tissues while selectively suppressing the signal from fat protons, MRIs use the fat saturation technique known as SPAIR (Fig 4). for Selective nulling of the fat signal, SPAIR combines inversion recovery with radiofrequency pulses [17,18].

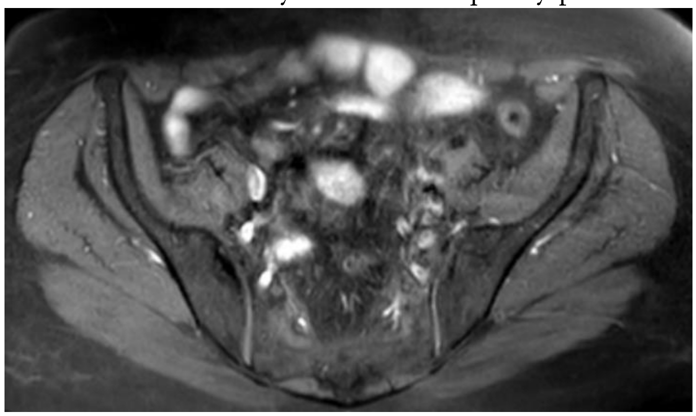

Fig 4: shows axial T1 SPAIR image on pelvis.

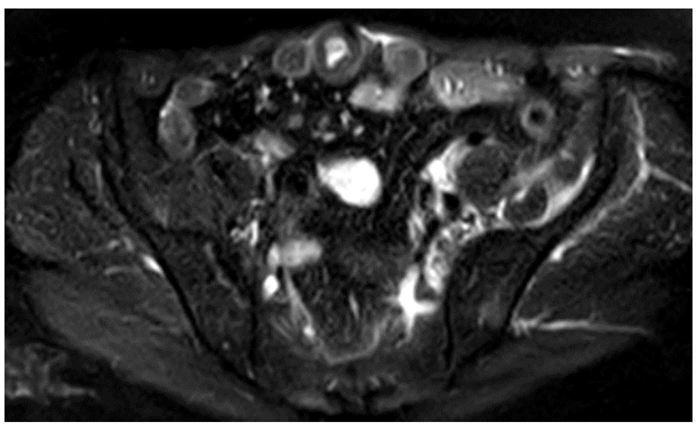

Fig 5: shows axial T2 SPAIR image on pelvis.

Using a specially designed radiofrequency (RF) pulse, the SPAIR fat saturation technique selectively inverts the magnetization of fat protons. The range of frequencies covered by this inversion pulse is intended to match to the resonance frequency of fat. Therefore, during the subsequent image acquisition, the fat protons' magnetization is flipped, effectively concealing their signal. Other tissues, like protons in water, on the other hand, continue to be magnetized and display their signal [17,18].

Its advantages are: ■ It provides strong fat suppression ■ Providing versatility in image acquisition, SPAIR can be used in a variety of imaging sequences, such as T1W and T2W sequences ■There are several body parts where SPAIR works well, including areas with greater amounts of fat. It can be applied to various anatomical locations, allowing for uniform body fat saturation [9,17,18].

Its disadvantages are: ■ Sensitivity to magnetic field inhomogeneities: The efficacy of SPAIR may be hampered in areas with magnetic field shifts such as those close to metal implants or air-tissue interfaces, which could lead to insufficient fat suppression. ■Possibility of incomplete fat saturation: SPAIR may not always result in total fat suppression, depending on the unique imaging parameters and patient characteristics. The possibility of residual fat signal diminishes the efficacy of fat suppression. ■ Prolonged scan time: Although the effect is usually negligible, applying more RF pulses for fat saturation may cause a tiny increase in the total scan time (9,17,18).

Conclusion:

In order to better visualize bone marrow lesions, assess fat in soft tissue masses, and more precisely define lesions following the administration of a paramagnetic contrast agent, fat suppression techniques are essential for obtaining clear and diagnostically valuable images in magnetic resonance imaging, especially in musculoskeletal imaging. In addition, it significantly reduces noise and eliminates chemical shift abnormalities, particularly at higher magnetic fields (≥ 3.0 Tesla). There are numerous techniques for suppressing fat, and each has advantages and disadvantages of its own. Selection of the appropriate technique requires careful evaluation of a number of factors. The objective of fat suppression (contrast enhancement vs. tissue characterization), the amount of fat present in the tissue being studied as well as the strength and the homogeneity of the primary magnetic field are these variables.

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