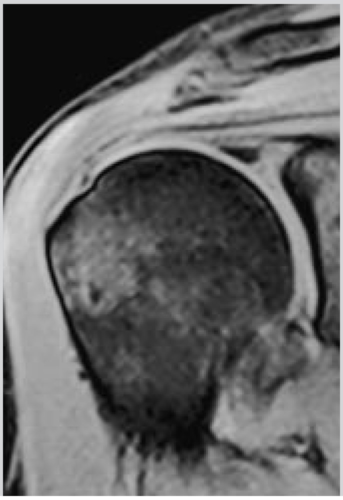
MRI Hot Topics



The Skinny on FatSat

SIEMENS
medical

The Skinny on FatSat

David Purdy, Ph.D.
Siemens Medical Solutions USA, Inc.

Figure 1:
Axial shoulder image using a MEDIC sequence with FatSat. (Courtesy Bill Leon, R.T., HealthSouth Doctors' Hospital, Coral Gables, FL, USA)

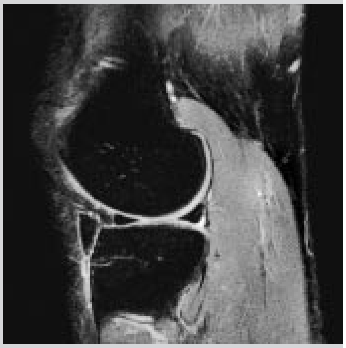


Figure 2:
Sagittal knee with "strong" FatSat.

Figure 3:
Sagittal knee with "weak" FatSat.

The bright signal from fat is often a hindrance to diagnosis in MR imaging. To meet the requirements of different protocols, Siemens offers an optimized version of FatSat, as well as three other fat suppression methods: water excitation, inversion recovery, and subtraction. These techniques have been enhanced to make high quality fat suppression part of the clinical routine.

Fat Saturation (FatSat)

Since the hydrogen nuclei of fat and water resonate at slightly different frequencies, it is possible to excite just the fat with a special RF pulse, and then destroy ("spoil") the resulting signal with a gradient pulse. This loss of fat signal is referred to as "saturation," a loose reference to a term from classical MR spectroscopy. The net magnetization of the water is preserved, so the normal pulse sequence that follows the FatSat pulse "sees" just the water signal [1].

In a perfectly uniform magnetic field, the FatSat pulse excites all of the fat in the imaging volume. Magnetic field nonuniformity caused by imperfect shimming or by the patient ("magnetic susceptibility" effects) can move the resonant frequency of some of the fat out of the narrow frequency range of the FatSat pulse, leading to regions of unwanted bright fat. The Siemens MAGNETOM acquires a 3D field map, and uses advanced software to customize the shim for the user's local acquisition volume, whether centered or off-center, ensuring good fat suppression to the edge of the main magnetic field (Figure 1). For advanced applications, manual placement of the reference frequency on the tissue spectrum is available.

The MAGNETOM Quick FatSat technique can be used to reduce acquisition time [2]. The FatSat pulse, which must have a significant duration for good selectivity, is ordinarily applied before each normal excitation pulse; this increases repetition time (TR) and acquisition time (TA). Even though fat saturation wears off rapidly, it is possible to apply the FatSat pulse less frequently, and Quick FatSat automates this while maintaining image quality.

Since some users prefer fat to be gray instead of black, the *syngo* software now offers a choice of strong or weak suppression (Figures 2 and 3). The software also optimizes the FatSat RF amplitude to maintain good suppression while compensating for the effects of TR and the number of slices.

Although FatSat significantly lengthens TR, it is useful at high field because it can be added to a wide range of pulse sequences without affecting other sequence parameters such as slice thickness. It works well with contrast agents, suppresses a wide band of fat frequencies, and causes little change in contrast among non-fatty tissues.

FatSat is not used for angiography unless contrast is injected, because susceptibility field errors can, within a small region like the neck, shift the resonant frequency of blood into the saturation bandwidth of the FatSat pulse. Without the T1-reducing effect of contrast, this blood will remain saturated as it flows, for example, into the head. Also, FatSat is not used at 0.2T, because the fat and water resonant frequency bands overlap substantially at low field strengths, and any FatSat pulse with a practical duration would significantly saturate some of the water signal.

Water Excitation

Compared to FatSat, water excitation permits faster acquisitions while eliminating the possibility of inadvertent water saturation. Instead of adding a long fat saturation pulse before the normal sequence excitation pulse, the excitation pulse is simply replaced by two or more pulses that, collectively, excite just the water nuclei. The first of these pulses excites both the fat and water nuclei. Because of the difference in their resonant frequencies, the fat and water spins quickly dephase from each other. The phase and the timing of the following pulse or pulses are selected to return the fat magnetization back to its original position [3]. The fat excitation is effectively undone, and fat is suppressed (Figures 4 and 5). The removal of the FatSat pulse benefits angiography by shortening TR and avoiding the possibility of saturating the blood signal [4]. At low field, water excitation makes spectral fat suppression possible because there is no unwanted saturation of water-containing tissues – ideal for post-contrast studies. Like FatSat, this is a frequency-selective technique. It is sensitive to shim and susceptibility effects, and benefits from the localized shim capabilities of Siemens MAGNETOM systems.

Inversion Recovery

When magnetic susceptibility effects caused by the patient reduce the effectiveness of the frequency-selective methods above, the fat signal can be suppressed by a completely different mechanism. Fat has a shorter T1 than most tissues, and its signal can be selectively eliminated by an inversion recovery sequence with a suitable inversion time (TI). Like the FatSat pulse, the inversion recovery pulse is positioned before the normal excitation pulse of a sequence. It inverts all of the tissue magnetization within a slice (“slice selective IR”) or the whole coil volume (“nonselective IR”). If this pulse is followed immediately by a normal pulse sequence, all of the tissues give negative signals, and the usual contrasts are inverted if real images are selected for viewing. If there is a delay between the inversion pulse and the normal sequence, the tissue magnetization starts to recover back to the equilibrium (main magnetic field) direction. At some tissue-specific delay time, each tissue will be halfway between its inverted and equilibrium state, and will have no net magnetization. If the normal pulse sequence is applied at this moment, there will be no MR signal from that tissue. Since fat recovers more quickly than other tissues, we can start the normal sequence after just a short wait to null the fat signal.

This is commonly referred to as STIR (Short TI Inversion Recovery) [5]. The advantage of STIR is that it maintains the quality of fat suppression even if the magnet shim is not perfect, if the magnetic susceptibility of the patient causes field errors, or if metal hardware is present. STIR is also advantageous at low field strengths (e.g., 0.2T), where the resonant frequency ranges of fat and water overlap, and frequency selective methods are less effective (Figure 6).

A disadvantage of STIR is that signal from any tissue with a T1 near that of fat will be attenuated, notably tissues that have absorbed contrast agent. Post-contrast studies should suppress fat with FatSat or water excitation. Another disadvantage is the need to wait for TI after each inversion pulse. This time constraint limits the number of pulse sequences that can use STIR. Siemens reduces this time penalty by collecting more than one line of data following the inversion pulse (TurboIR).

Subtraction

Image subtraction is a highly effective method of removing the background signal from pairs of pre- and post-contrast images, and much of this background signal is fat. Siemens’ *syngo* software was specifically designed to perform these subtractions in a user-friendly manner.

Conclusion

Siemens offers not only FatSat, but also three other fat suppression techniques to match the requirements of a broad range of imaging protocols and clinical applications. Each of these four techniques benefits from enhancements to provide greater flexibility, speed, and ease of use.

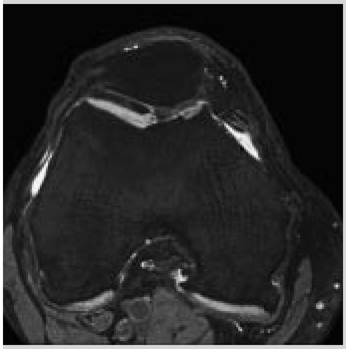


Figure 4:
Axial knee at 1.5T (Courtesy Bill Leon, R.T., HealthSouth Doctors’ Hospital, Coral Gables, FL, USA)

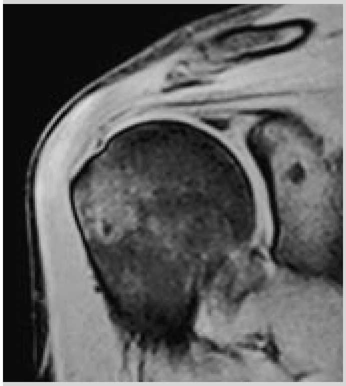


Figure 5:
Coronal shoulder at 0.2T (Courtesy Craig Platenberg, M.D., Wide Open MRI of Hagerstown, MD, USA)

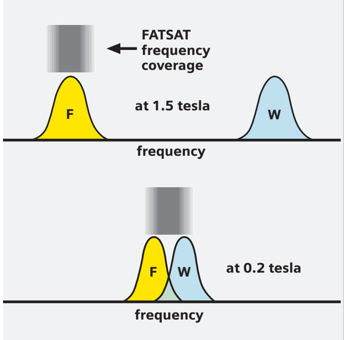


Figure 6:
At 1.5T, the fat (F) and water (W) resonant frequencies are well separated, and the fat magnetization can be saturated by a frequency-selective RF pulse without affecting the water signal. At 0.2T, the resonance peaks of fat and water have significant overlap, and it is difficult to suppress the fat magnetization without also attenuating the water signal.

MAGNETOM World

Please contact in USA:

Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway
Malvern, PA 19355
(6 10) 2 19–63 00

in Japan:

Siemens-Asahi
Medical Technologies Ltd.
Takanawa Park Tower 14 F
20–14, Higashi-Gotanda 3-chome
Shinagawa-ku
Tokyo 141-8641
(+81) 354 234 001

in Asia/Pacific:

Siemens Medical Solutions
Asia Pacific Headquarters
c/o Siemens Advanced Engineering Pte Ltd.
Block 28 Ayer Rajah Crescent No. 06–08
Singapore 139959
(+65) 8 715 888

Or contact your local Siemens sales representative

Siemens AG, Medical Solutions
Magnetic Resonance
Henkestr. 127, D-91052 Erlangen
Germany
Telephone: ++49 9131 84-0
www.SiemensMedical.com

Visit the New MAGNETOM World

www.SiemensMedical.com/MAGNETOM-World

- Learn more about Siemens MR users worldwide and about the broad range of clinical and research applications possible with Siemens' MR solutions.
- Find out why leading experts choose Siemens!
- Download other MRI Hot Topics issues.
- Send us your questions and comments.

References

[1] P.A.Bottomley, T.H. Foster, and W.M. Leue, "In vivo Nuclear Magnetic Resonance Chemical Shift Imaging by Selective Irradiation," Proc. Natl. Acad. Sci. U.S.A. 81 (1984) 6856; A.Haase, J.Frahm, J.Hänicke, and D. Matthaei, "1H NMR Chemical Shift Selective (CHESS) Imaging," Phys. in Med. & Biol.30 (1985) 341.

[2] J.Paul Finn, David M. Thomasson, James R. Moore, David E.Purdy, Susan Ascher, Richard Patt, and Gerhard Laub, "Minimum-Cost Presaturation by Slice Segmentation in Fast 2-D Gradient-Echo Imaging," Proceedings of the Society of Magnetic Resonance, 4th Annual Meeting (1996) 1475.

[3] David Thomasson, David Purdy, and J. Paul Finn, "Phase Modulated Binomial RF Pulses for Fast Spectrally Selective Musculoskeletal Imaging," Magnetic Resonance in Medicine 35 (1996) 563.

[4] Andrew W. Litt, David M. Thomasson, P. Licata, "Spatial-Spectral Water Excitation FISP MRA of the Extra-Cranial Carotid Arteries, "Proceedings of the Society of Magnetic Resonance, 3rd Annual Meeting, (1995) 1563.

[5] G.M. Bydder and I.R. Young, "MR Imaging: Clinical Use of the Inversion Recovery Sequence," J. Comput. Assist. Tomogr. 9 (1985) 659.

Siemens **Medical**
Solutions that help

Bestell-Nr. A91100-M2220-B044-1-7600
Printed in Germany
BKW 64044 WS 01036.