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Fat and Water Differentiation by Nuclear Magnetic Resonance Imaging

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Following our article entitled "Fat and Water Differentiation by Nuclear Magnetic Resonance Imaging" (*1*), it was suggested that it would be helpful to summarize our findings in tabular form. The table presented here highlights the advantages and disadvantages of numerous techniques that have been used in MRI for fat and water differentiation. Our "title" for each subcategory is followed by the original references relating to that method. This table is intended to be used as a quick reference guide. For a more elaborate treatment of the subject, we suggest that the reader refer to the full paper.

Method	Pros	Cons
T_1-null Method (*2*, *3*)	• no special requirements for high or homogeneous static magnetic field • multiple-slice • high T_1 contrast	• not true fat- or water-only images, but suppression of component with certain T_1 • prior knowledge/estimation of T_1 values required • may result in poor S/N
T_2-calculated Images (*4*)	• no special requirements for high or homogeneous static magnetic field • multiple-slice	• not true fat- or water-only images, but images of components with certain T_2 • range of T_2 values for fat and water often overlap
Selective Excitation (*5*-*7*)	• true fat- or water-only images	• requires static field high and homogeneous enough to resolve the two resonances • single-slice
Selective Excitation Using Stimulated Echo Imaging (*8*)	• true fat- or water-only images • multiple-slice	• requires static field high and homogeneous enough to resolve the two resonances • differential T_1 weighting across the slices • inherent poor S/N
Selective Suppression (*9*-*11*)	• true fat- or water-only images • multiple-slice	• requires static field high and homogeneous enough to resolve the two resonances • may result in differential suppression across the slices

Method	Pros	Cons
Asymmetric Spin-Echo (*12, 13*)	• true fat- or water-only images • lower static field requirements than most other chemical shift imaging techniques • multiple-slice	• phase-correction algorithms, relatively extensive post-processing • at least two experiments required even if only one component is of interest • data manipulation may result in degradation of the image by motion artifacts • may suffer from dynamic range problems
Asymmetric Multiple-Echo Spin-Echo (*14*)	• true fat- or water-only images • lower static field requirements than most other chemical shift imaging techniques • multiple-slice • inherent B_0 information available for phase-correction	• phase-correction algorithms, relatively extensive post-processing • data manipulation may result in degradation of the image by motion artifacts • may suffer from dynamic range problems
Gradient Reversal in Slice Selection Direction (*15*)	• true fat- or water-only images • multiple-slice	• requires static field high and homogeneous enough to resolve the two resonances • requires gradient linearity • slice number and thickness limitations
Spectroscopic Imaging (*16, 17*)	• true fat- or water-only images • multiple-slice • extra spectral information	• requires static field high and homogeneous enough to resolve the two resonances • longer imaging times to achieve the same spatial resolution • relatively extensive post-processing (3D)
Coupled-Spin Imaging (*18-21*)	• true fat-only images • no special requirements for high or homogeneous static magnetic field	• data manipulation may result in degradation of the image by motion artifacts • may suffer from dynamic range problems
C-13 Imaging (*22*)	• water-excluded images	• inherent limitations, such as low sensitivity, low concentration, scalar coupling • no water-only images
Diffusion-Weighted Imaging (*23*)	• fat images • multiple-slice	• poor S/N • motion artifact • no direct water-only images

References

1. E. Kaldoudi and S. C. R. Williams, "Fat and Water Differentiation by Nuclear Magnetic Resonance Imaging," *Concepts Magn. Reson.*, **1992**, *4*, 53-71.

2. M. A. Foster, J. M. S. Hutchison, J. R. Mallard, and M. Fuller, "Nuclear Magnetic Resonance Pulse Sequence and Discrimination of High- and Low-Fat Tissues," *Magn. Reson. Imaging.*, **1984**, *2*, 187-192.

3. G. M. Bydder and I. R. Young, "MR Imaging: Clinical Use of the Inversion Recovery Sequence," *J. Comput. Assist. Tomogr.*, **1985**, *9*, 659-675.

4. K. Gersonde, T. Tolxdorff, and L. Felsberg, "Identification and Characterization of Tissues by T_2-Selective Whole-Body Proton NMR Imaging," *Magn. Reson. Med.*, **1985**, *2*, 390-401.

5. L. D. Hall, S. Sukumar, and S. L. Talagala, "Chemical-Shift-Resolved Tomography Using Frequency-Selective Excitation and Suppression of Specific Resonances," *J. Magn. Reson.*, **1984**, *56*, 275-278.

6. P. M. Joseph, "A Spin Echo Chemical Shift Imaging Technique," *J. Comput. Assist. Tomogr.*, **1985**, *9*, 651-658.

7. J. A. B. Lohman, R. J. Ordidge, and A. Connelly, "Spin Echo Imaging of Multiple Chemical Shifts," *Magn. Reson. Med.*, **1987**, *5*, 83-86.

8. A. Haase and J. Frahm, "Multiple Chemical-Shift-Selective NMR Imaging Using Stimulated Echoes," *J. Magn. Reson.*, **1985**, *64*, 94-102.

9. B. R. Rosen, V. J. Wedeen, and T. J. Brady, "Selective Saturation NMR Imaging," *J. Comput. Assist. Tomogr.*, **1984**, *8*, 813-818.

10. A. Haase, J. Frahm, W. Hanicke, and D. Matthaei, "H-1 NMR Chemical Shift Selective (CHESS) Imaging," *Phys. Med. Biol.*, **1985**, *30*, 341-344.

11. P. J. Keller, W. W. Hunter, and P. Schmalbrock, "Multisection Fat-Water Imaging with Chemical Shift Selective Presaturation," *Radiology*, **1987**, *164*, 539-541.

12. R. E. Sepponen, J. T. Sipponen, and J. I. Tanttu, "A Method for Chemical Shift Imaging: Demonstration of Bone Marrow Involvement with Proton Chemical Shift Imaging," *J. Comput. Assist. Tomogr.*, **1984**, *8*, 585-587.

13. W. T. Dixon, "Simple Proton Spectroscopic Imaging," *Radiology*, **1984**, *153*, 189-194.

14. S. C. R. Williams, M. A. Horsfield, and L. D. Hall, "True Water and Fat MR Imaging with Use of Multiple-Echo Acquisition," *Radiology*, **1989**, *173*, 249-253.

15. A. Volk, B. Tiffon, J. Mispelter, and J. M. Lhoste, "Chemical Shift-Specific Slice Selection. A New Method for Chemical Shift Imaging at High Magnetic Field," *J. Magn. Reson.*, **1987**, *71*, 168-174.

16. L. D. Hall and S. Sukumar, "Chemical Microscopy Using a High-Resolution NMR Spectrometer. A Combination of Tomography/Spectroscopy Using either H-1 or C-13," *J. Magn. Reson.*, **1982**, *50*, 161-164.

17. L. D. Hall and S. Sukumar, "Three Dimensional Fourier Transform NMR Imaging. High Resolution Chemical Shift Resolved Planar Imaging," *J. Magn. Reson.*, **1984**, *56*, 314-317.

18. A. G. Webb, S. C. R. Williams, and L. D. Hall, "Generation of Coupled Spin-Only Images Using Multiple-Echo Acquisition," *J. Magn. Reson.*, **1989**, *84*, 159-165.

19. L. D. Hall, T. J. Norwood, and S. C. R. Williams, "Coupled-Spin-Filtered Imaging in an Inhomogeneous Magnetic Field," *J. Magn. Reson.*, **1988**, *79*, 363-368.

20. C. L. Dumoulin and D. Vatis, "Water Suppression in H-1 Magnetic Resonance Images by the Generation of Multiple-Quantum Coherence," *Magn. Reson. Med.*, **1986**, *3*, 282-288.

21. C. L. Dumoulin, "Suppression of Water and Other Noncoupled Spins by Homonuclear Polarization Transfer in Magnetic Resonance Imaging," *Magn. Reson. Med.*, **1986**, *3*, 90-96.

22. D. W. Kormos and H. N. Yeung, "NMR Imaging of C-13 in Animal Tissues," *Magn. Reson. Med.*, **1987**, *4*, 500-505.

23. M. I. Altbach, M. A. Mattingly, M. F. Brown, and A. F. Gmitro, "Magnetic Resonance Imaging of Lipid Deposits in Human Atheroma via a Stimulated-Echo Diffusion-Weighted Technique," *Magn. Reson. Med.*, **1991**, *20*, 319-326.