Large-field-of-view test-object for assessment of fat suppression in body DW-MRI

Jessica M Winfield[1], Naomi HM Douglas[1], David J Collins[1], and Nandita M deSouza[1]
[1]*Institute of Cancer Research, Sutton, Surrey, United Kingdom*

TARGET AUDIENCE: Physicists and clinical scientists using diffusion-weighted magnetic resonance imaging (DW-MRI).

BACKGROUND: Suppression of the signal from fat is essential in DW-MRI. The techniques available for fat suppression vary between manufacturers and models of scanners and between versions of software. The optimal method for fat suppression depends on application and magnetic field strength and may require optimisation for a specific protocol, particularly at 3 T. Previous studies have demonstrated the need for combined methods of fat suppression at 3 T. [1] Applications such as DW-MRI in bone or muscle may also require combinations of techniques to simultaneously suppress signals from saturated and unsaturated moieties in fat. A suitable test-object for assessment of fat suppression body DW-MRI should: 1. occupy a large field-of-view (FOV); 2. have a fat spectrum that matches the positions and relative intensities of the main fat resonances observed *in vivo*; 3. have longitudinal relaxation times that are closely matched to human fat at 1.5 T and 3 T; 4. be composed of stable, inexpensive and widely available materials.

Figure 1: Test-object.

PURPOSE: To develop a test-object for assessment of fat suppression in DW-MRI across a large FOV. To use the test-object to develop techniques to simultaneously suppress saturated and unsaturated components of the fat signal at 1.5 T and 3 T.

METHODS: The test-object is a Perspex outer cylinder (height 300 mm, inner diameter 185 mm) with an inner cylinder (inner diameter 140 mm) lying coaxially (Figure 1). The inner cylinder is filled with deionised water doped with copper sulphate (770 mg/L $CuSO_4.5H_2O$, Sigma-Aldrich) and sodium chloride (2000 mg/L NaCl, Sigma-Aldrich). The annulus is filled with corn oil (Mazola). The MR spectrum of corn oil has been shown to contain peaks arising from protons associated with saturated (strongest peak at 1.3 ppm) and unsaturated (5.4 ppm) moieties with very similar spectral positions and relative intensities to the main lipid resonances observed in subcutaneous and marrow fat.[2,3] The test-object and volunteers were imaged using 1.5 T (Avanto, Siemens) and 3 T (Achieva, Philips, equipped with Multi Transmit) MR scanners using protocols which had been previously optimised for abdominal DW-MRI. The test-object was placed at ~45degrees to the z-axis in order to obtain an elliptical cross-section in transverse images. Fat suppression was applied using Spectral Adiabatic Inversion Recovery (SPAIR), Fat Saturation (Fat Sat), Inversion Recovery (IR), Water Excitation (WE) and Slice-Selective Gradient Reversal (SSGR) on the 1.5 T scanner and using SPAIR, Spectral Inversion Recovery (SPIR), IR and SSGR at 3 T.

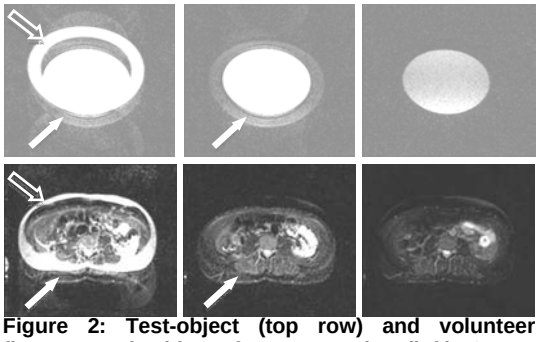

Figure 2: Test-object (top row) and volunteer (bottom row) without fat suppression (left); SPAIR (centre); and IR (TI=260 ms) combined with WE (right) (1.5 T, b=0). Chemical-shifted signals from saturated fat (open arrows) and unsaturated fat (filled arrows) are marked on the images.

RESULTS AND DISCUSSION: Images of the test-object obtained without fat suppression demonstrate the presence of signals from saturated and unsaturated components of the fat signal and mirror the appearances in the volunteer (Figure 2). At 1.5 T spectrally-selective techniques showed good suppression of the saturated fat but the unsaturated fat was unsuppressed in both the test-object and the volunteer (Figure 2). SPAIR achieved more homogenous suppression of the saturated fat than Fat Sat or WE in both test-object and volunteer. At 3T, spectrally-selective techniques (SPAIR, SPIR and SSGR) applied alone resulted in inhomogeneous suppression of the saturated fat signal in the test-object and volunteer. The inversion delay of IR images was adjusted to optimise suppression of the saturated or unsaturated fat. The optimal delay times for the test-object were within 20-40 ms of those for the volunteer (Table 1). Inversion delays were selected to suppress the unsaturated component of the fat signal and combined with spectrally-selective methods which suppressed the saturated component of the fat. Delay times at the lower end of the ranges shown in Table 1 were selected in order to minimise concomitant suppression of the water signal. At 1.5 T, IR and WE in combination resulted in the best suppression of the saturated and unsaturated fat signals in the test-object and volunteer (Figure 2). At 3 T the combination of IR and SSGR achieved the most effective suppression of both components of the fat signal in the test-object and volunteer (Figure 3).

		Inversion delay / ms	
		Corn oil	**Subcutaneous fat**
Saturated	1.5 T	140-160	180
	3 T	200-220	220-240
Unsaturated	1.5 T	240-280+	260-280+
	3 T	260-300+	260-300+

Table 1: Inversion delays to suppress saturated and unsaturated fat at 1.5 T and 3 T.

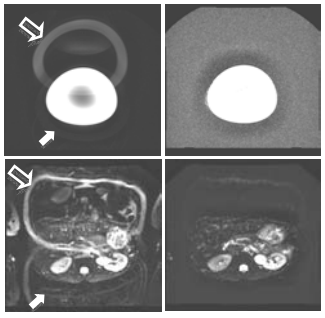

Figure 3: Test-object (top) and volunteer (bottom) without fat suppression (left) and using IR (TI=260 ms) combined with SSGR (right) (3 T, b=0). Chemical-shifted signals from saturated fat (open arrows) and unsaturated fat (filled arrows) are marked on the images.

CONCLUSIONS: Corn oil is a suitable material for investigation of spectrally-selective and T1-dependent fat-suppression techniques. The size and shape of the test object are suitable for investigation of fat suppression over a large FOV. We have used the test-object to develop combinations of fat-suppression techniques to simultaneously suppress saturated and unsaturated components of the fat signal at 1.5 T and 3 T. Suppression of both components of the fat signal is particularly relevant in DW-MRI studies of tissues which contain a significant proportion of fat, for example bone marrow and omentum. We have translated the techniques from the test-object to *in vivo* imaging. Only small adjustments to delay times were required for optimisation *in vivo*. The test-object can be used to reduce the amount of volunteer imaging required in optimisation of protocols, which is particularly relevant when setting up multi-centre studies.

REFERENCES: (1) Blackledge MD, Higgins D, Koh D-M, deSouza NM, Leach MO, Collins DJ. *Proc Intl Soc Mag Reson Med.* 2010;4721. (2) Kuroda K, Oshio K, Mulkern RV, Jolesz FA. *Magn Reson Med.* 1998;40:505-510. (3) Wang L, Salibi N, Wu Y, Schweitzer ME, Regatte RR. *J Magn Reson Imaging. 2009;*29:1457-1464.

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