Phase sensitive inversion recovery with simultaneous dark fat rendering by virtual chemical inversion

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Background: On delayed-enhancement (DE-CMR) images, both fat and infarcted myocardium appear bright making them difficult to differentiate. Standard chemical shift fat-suppression ($FatSat_{CS}$) consists of a fat-frequency selective saturation followed by a readout. This approach is suboptimal in clinical DE-CMR sequences which typically have long readout times (100–200ms), and when the center of k-space is acquired (for linear reordering) the fat magnetization has significantly recovered (T_1 = 290ms, 3T). Centric reordering can overcome this limitation, but at the cost of blurring artifacts.

The phase sensitive inversion recovery (PSIR) variant of DE-CMR avoids the need to precisely set the inversion time through the acquisition of a reference data set interleaved between image acquisitions. Phase sensitive reconstruction removes the background phase while preserving the overall sign of the magnetization by subtracting the phase of the data acquired during the reference scan from the main data set [1]. Standard $FatSat_{CS}$ can be activated in PSIR, but usually does not result in dark fat since the phase sensitive reconstruction rescales the image brightness based on the most negative species in the image, typically causing the fat to appear bright.

We hypothesized that modifying the PSIR reference acquisition via a Dixon-type approach, by acquiring the reference image with a different TE such that fat is 180° out of phase from water, could provide PSIR images that simultaneously show dark fat without added acquisition time. The result is a virtual chemically selective inversion ($FatSat_{VCSI}$), without increased SAR and at no cost to signal-to-noise from pulse imperfections.

Methods: PSIR images in phantoms and patients (n = 23) were acquired at 1.5T (n = 11, MAGNETOM Avanto, Siemens) and 3T (n = 12, MAGNETOM Verio, Siemens) with a segmented gradient-echo readout. In phantoms, we studied the relationship of readout duration (by varying the number of lines per segment) to fat signal. $FatSat_{CS}$ efficacy was studied for both centric and linear reordering. In patients, three sequential PSIR images were acquired: no fat suppression, $FatSat_{CS}$ and the $FatSat_{VCSI}$ with the same parameters including inversion time. Regions of interest (ROIs) were drawn in pericardial and subcutaneous fat and left ventricular blood pool. The performance of each technique was evaluated by comparing the fat-to-blood signal ratios.

Results: The phantom results demonstrate that increasing readout time reduces the efficacy $FatSat_{CS}$ with linear reordering, but not for centric (figure 1a). With centric reordering, significant blurring artifacts occurred (figure 1b) with clinically relevant readout times. In patients, $FatSat_{CS}$ (linear) had no effective fat saturation (table 1), while $FatSat_{VCSI}$ provided effective fat suppression. Figure 2 shows patient images of all fat suppression techniques including linear and centric reordering.

Conclusion: By modifying the reference acquisition of a PSIR scan, we provide PSIR images with fat suppression in a single acquisition. No additional data acquisition, RF pulses, or increased scan time is required.

Reference: [1] Kellman, P, et al, MRM, 47:372-383 (2002)

Figure 1

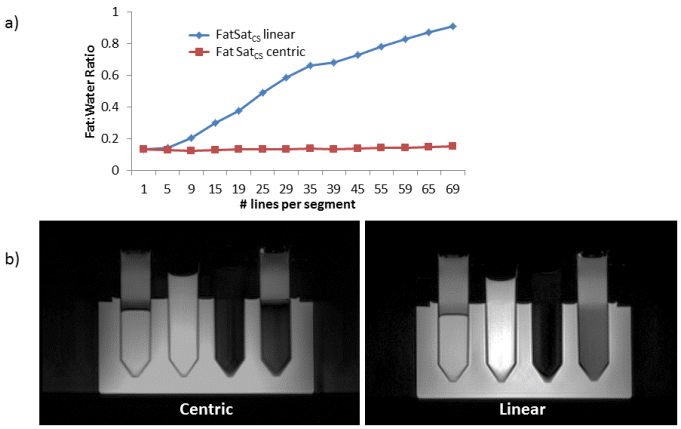
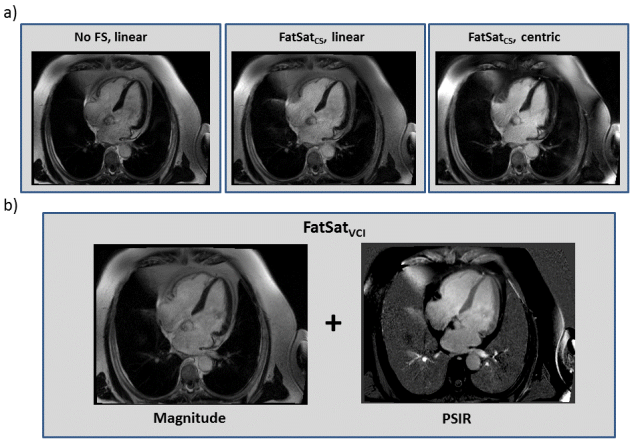


Figure 2



	1.5T				3T			
	No Fat Sat	FatSat (linear)	FatSat (centric)	FatSat (VCSI)	No Fat Sat	FatSat (linear)	FatSat (centric)	FatSat (VCSI)
Subcutaneous Fat	1.03 ±0.04	1.01 ±0.08 #	0.93 ±0.05 #	0.64 ±0.04*	1.07 ±0.03	1.09 ±0.07 #	1.15 ±0.06 #	0.54 ±0.04*
Pericardial Fat	1.02 ±0.05	1.03 ±0.11 #	0.90 ±0.05 #	0.75 ± 0.05*	1.05 ±0.02	1.1 ±0.02 #	1.12 ±0.11 #	0.62 ±0.02*

Mean ± standard error of the mean, *: different to No Fat Sat, p <0.001; #: identical to No Fat Sat, p >0.05.