Jenista et al. Journal of Cardiovascular Magnetic Resonance 2013, 15(Suppl 1):P19
http://www.jcmr-online.com/content/15/S1/P19

Journal of Cardiovascular Magnetic Resonance

POSTER PRESENTATION Open Access

Virtual chemical inversion - a novel fat suppression technique for T1-weighted cardiac imaging with improved delineation of the fat-myocardium interface

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From 16th Annual SCMR Scientific Sessions
San Francisco, CA, USA. 31 January - 3 February 2013

Background

Fat-saturation and T1-weighting are fundamental for tissue differentiation, but combining these techniques is challenging. For instance, standard chemically selective saturation (CHESS) pulses provide insufficient fat-suppression with routine delayed enhancement imaging [1]. Fat-water separation using multi-echo Dixon techniques can robustly separate fat and water into individual images, but in the fat-suppressed (water only) image, fat may retain a significant amount of signal making identification of the fat-water border difficult.

We previously described a new technique (Virtual Chemical Inversion, VCI, [1]) which has the advantage of providing T1-weighted images with and without fat suppression in a single acquisition without the need for additional data acquisition, RF pulses, or increased scan time. In this study, we compare the ability of the CHESS, a multi-echo Dixon technique (VARPRO, [2]), and our new method (VCI) to completely delineate the myocardium-fat interface in patients, and the level of fat suppression in phantoms.

Methods

Phantoms - A phantom with tubes of oil and water was imaged at 1.5T (MAGNETOM Avanto) using CHESS, VARPRO and VCI. B0 offsets ranging from 0 Hz to 100 Hz were tested. Regions of interest (ROIs) were drawn in the fat and water tubes and fat suppression was evaluated by calculating the fat-water signal ratio.

Patients - Patient images were acquired in 10 consecutive patients at 1.5T with VARPRO, VCI, and DIR-TSE with SPAIR, a commonly used method for pre-contrast fat suppression [3]. Two experienced readers estimated the percentage of the visible RV myocardium - fat interface. ROIs were drawn in the myocardium and pericardial fat. The ratio of fat to myocardium signal was calculated. Analyses were performed using ANOVA with Bonferroni correction.

Results

In the phantom, VCI and VARPRO led to significant fat signal reduction, with no variation in the fat-water signal over a range of 90 Hz. The CHESS method provided little fat suppression for clinical readout times, and was sensitive to resonance offset (Figure 1). In patients (Figure 2), on average, 94% of the RV myocardium-fat interface was seen with VCI, which was statistically different from both VARPRO(69%) and DIR-TSE (50%). By quantitative analysis, VCI was shown to have the lowest fat-myocardium ratio(0.43) followed by VARPRO (0.86) and DIR-TSE (0.96)(Figure 2).

Conclusions

VCI exhibited excellent fat-water separation in both phantoms and patients, consistently providing fat suppression to a higher degree than both DIR-TSE and VARPRO, allowing for nearly complete delineation of the RV myocardium- fat interface.

Funding

None

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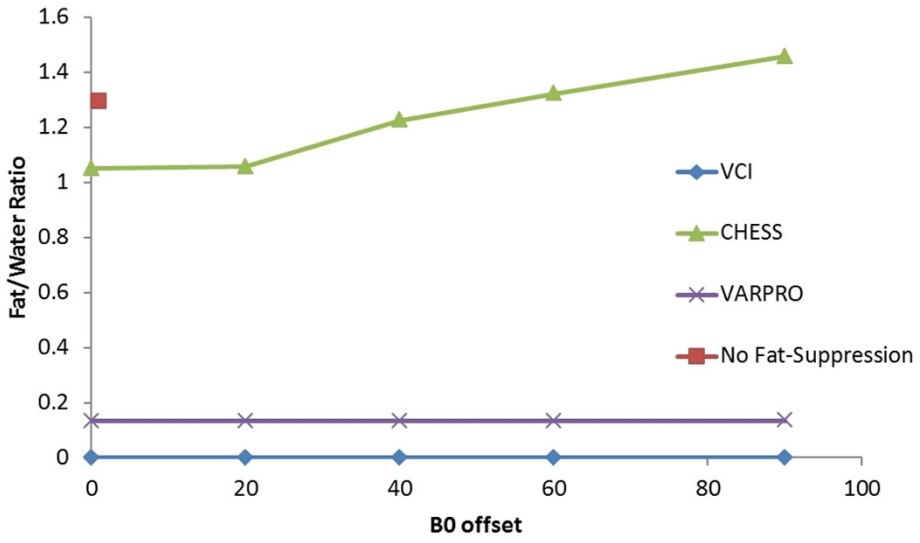
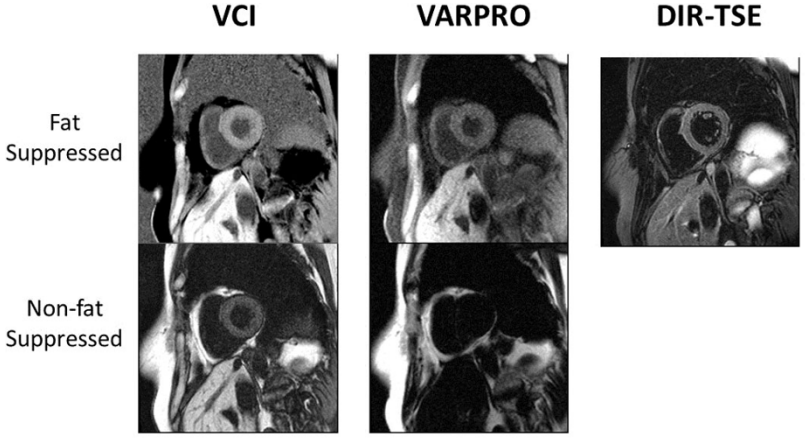


Figure 1 Phantom results. In the phantom, VCI provided uniform fat signal suppression over a range of 90 Hz. The VARPRO provided slightly less fat suppression, but was uniform over the entire range of offsets. The CHESS provided no significant fat suppression for any offset.



	Visual Analysis		Quantitative Analysis	
	% RV myocardium – fat interface visualized		Fat - RV Myocardium Ratio	
	Mean % ± SD	P-value vs. VCI	Mean ± SD	P-value vs. VCI
TSE	50 ± 20	<0.0001	0.96 ± 0.34	<0.0001
VARPRO	69 ± 20	0.0015	0.68 ± 0.27	0.0003
VCI	94 ± 5	--	0.43 ± 0.07	--

Figure 2 Patient results. Top: Patient example images comparing VCI, VARPRO and DIR-TSE. Fat suppression in the DIR-TSE is done using a SPAIR pulse (Spectrally Attenuated Inversion Recovery). The VCI provides clear contrast between the RV-myocardium and pericardial fat, while the entire interface is not clearly delineated on the VARPRO and DIR-TSE fat suppressed images. Bottom - Comparison of the visual and quantitative scores in patients. The VCI allows an average of 94% of the interface to be seen, and has the lowest fat-myocardium ratio. Note that smaller fat-myocardium ratios signify improved fat suppression.

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Published: 30 January 2013

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doi:10.1186/1532-429X-15-S1-P19
Cite this article as: Jenista *et al.*: Virtual chemical inversion - a novel fat suppression technique for T1-weighted cardiac imaging with improved delineation of the fat-myocardium interface. *Journal of Cardiovascular Magnetic Resonance* 2013 **15**(Suppl 1):P19.