A New Fat-suppressed Spin-Echo Imaging Using Hyperbolic-Secant Pulses

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Target audience: Researchers in water/fat separation

Purpose: Fat-suppression techniques are extensively used in clinical applications to reduce the fat-related issues such as chemical shift, motion, and dynamic range problems. Among many fat-suppression techniques, the methods based on selective saturation[1] and inversion recovery (IR)[2] have been most widely used. However, both selective saturation and IR techniques have some limitations because they require additional RF pulses and an increased scan time. In case of spin-echo (SE) based sequences, gradient reversal technique[3] can be used as it offers a better performance without additional RF pulses or scan time. In this study, we propose a new fat-suppressed spin-echo imaging technique, which simply uses the original hyperbolic secant (HS) RF pulses for $\pi/2$ excitation and π refocusing in a conventional SE sequence without any sequence modification or using additional RF pulses.

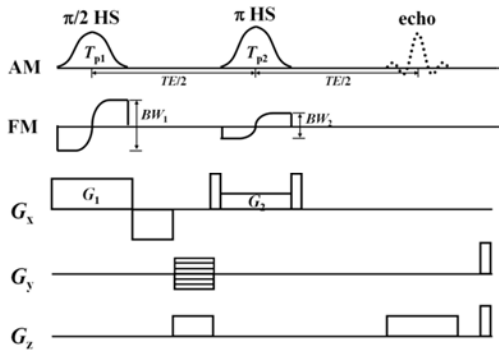

Figure 1. The sequence diagram of the proposed fat-suppression technique.

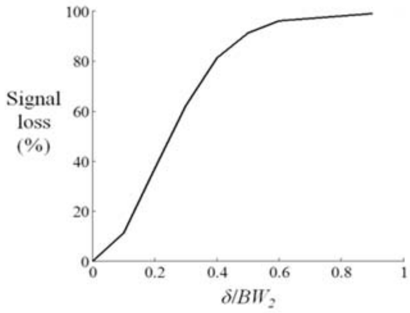

Figure 2. Signal loss as a function of δ/BW_2.

Methods: When HS pulses are used for $\pi/2$ excitation and π refocusing in the SE sequence, non-linear phase variation is produced by each HS pulse across the slice-selective direction and it needs to be compensated to avoid a signal loss. The previous work done by J-Y Park et al. provides general conditions for the non-linear phase compensation[4]. One of the general conditions is to satisfy $[T_{p1} = T_{p2}, BW_1 = 2BW_2$, and $G_1 = 2G_2]$, where T_p is a pulse length, BW is a pulse bandwidth, and G is the amplitude of a slice-selective gradient. Subscripts 1 and 2 indicate $\pi/2$ excitation and π refocusing, respectively. The sequence diagram satisfying this condition is presented in Fig. 1. When using this condition, however, the non-linear phase compensation cannot be fully achieved with the existence of a frequency offset (δ) arising from some sources other than the field gradient such as chemical shift and B_0 inhomogeneity. The remaining phase variation increases as δ/BW_2 increases and, thus, the signal loss takes place in the voxels having the frequency offset δ[4]. Besides, a slice mismatch also occurs between $\pi/2$ excitation and π refocusing in the presence of δ, yielding an additional signal loss. Figure 2 shows the signal loss as a function of δ/BW_2, considering the remaining phase variation as well as the slice mismatch. At this stage, we can come up with an idea that this signal loss can be used for suppressing the signals from fat components having a chemical shift of δ = 3.5 ppm if the bandwidths of HS pulses are properly determined. To verify the proposed fat suppression technique, both phantom and in vivo experiments were performed using a 3T MRI system (ISOL technology, Korea) with the following parameters: TE/TR = 30ms/300ms for phantom imaging and TE/TR = 90ms/700ms for in vivo imaging, FOV = 256×256 mm^2, matrix size = 256×256, and slice thickness = 5 mm. The $\pi/2$ and π HS pulses were used with $T_{p1} = T_{p2}$ = 8 ms and BW_1/BW_2= 2.5 kHz/1.25 kHz. For comparison, two more SE images were acquired without fat suppression: One using sinc pulses with T_p = 8 ms. The other one using HS pulses having T_{p1}/T_{p2} = 8ms/4ms and $BW_1 = BW_2$ = 1.25 kHz, which satisfies another condition for the non-linear phase compensation with no signal loss in the presence of δ[4].

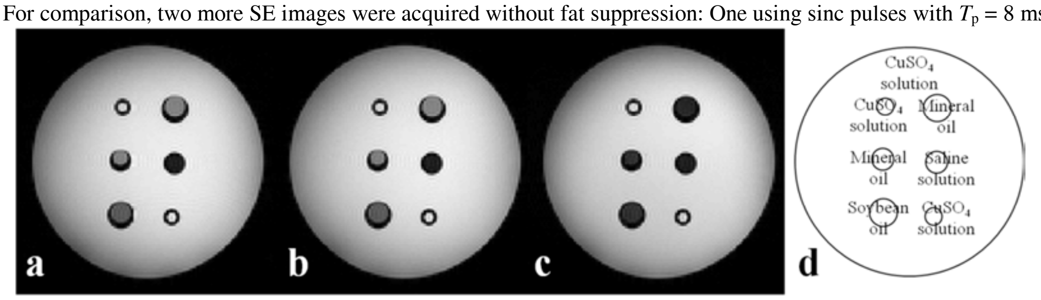

Figure 3. Phantom SE images using (a) sinc pulses, (b) HS1 pulses with $[T_{p1} = T_{p2}]$, and (c) HS1 pulses with $[BW_1 = 2BW_2, G_1 = 2G_2]$ from (d) a custom-made phantom.

Results: As shown in Fig. 3, mineral oil and soybean oil were well suppressed with the proposed fat suppression technique (Fig. 2c), when compared to SE images acquired with sinc pulses (Fig. 2a) and HS pulses of $T_{p1} = T_{p2}$ (Fig. 2b). Human brain images acquired using different SE imaging techniques are also presented in Fig. 4. When compared to SE images obtained from two other SE imaging methods without fat suppression, it is apparent that the proposed method accomplished a satisfactory fat suppression, especially in the periphery of the brain, i.e., in scalp.

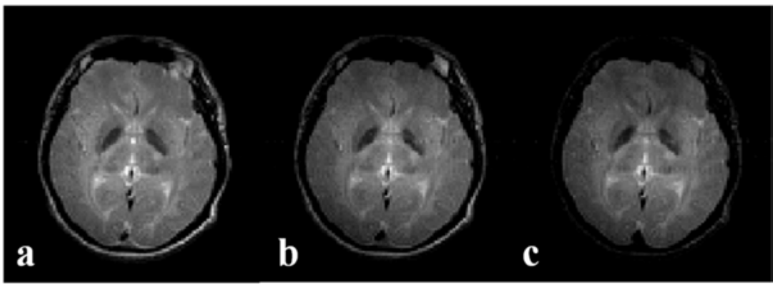

Figure 4. In vivo SE images acquired using (a) sinc pulses, (b) HS pulses with $[T_{p1} = T_{p2}]$, and (c) HS pulses with $[BW_1 = 2BW_2, G_1 = 2G_2]$.

Conclusions: A new fat-suppressed spin-echo imaging technique was suggested and its performance was successfully demonstrated by phantom and human brain imaging. The proposed technique is appealing in that additional RF pulses or any sequence modification is not needed. Furthermore, a high degree of tolerance to B_1 inhomogeneity and excellent slice selection of the HS pulse would be another benefit of the proposed techniques.

References: 1. Rosen BR, Wedeen VJ, Brady TJ. Selective saturation NMR imaging. J Comput Assist Tomogr 1984;8:813–818. 2. Bakker, C.J.C et al, Restoration of signal polarity in a set of inversion recovery NMR images. IEEE TMI 1984; 3:197-202. 3. Park HW et al, Gradient reversal technique and its applications to chemical shift related NMR imaging. MRM 1987; 4(6):526-36. 4. Park J-Y et al, Spin-echo MRI using $\pi/2$ and π hyperbolic secant pulses. MRM 2006; 55:848-857.