Comparison of Two Fat Imaging Techniques: Water-suppressed T1W TSE vs. Water-Saturated b-SSFP

Q. Peng[1], R. W. McColl[1], J. Wang[1], J. M. Chia[2], P. T. Weatherall[1]

[1]Department of Radiology, UT Southwestern Medical Center, Dallas, TX, United States, [2]Philips Medical Systems, Cleveland, OH, United States

Introduction

Human body fat imaging and quantification is of great importance for clinical and research purposes. It is now established that excessive accumulation of regional adipose tissue is closely correlated with type II diabetes, cardiovascular disease, and cancer. In healthy subjects, especially children, fat quantification with MRI is preferable to computerized tomography (CT) because it imposes no radiation exposure. Traditionally, T1-weighted (T1W) turbo spin echo (TSE), is used for fat imaging because it offers a reasonable fat to lean-tissue contrast-to-noise ratio (CNR) in a relatively short scan time. However, the contrast between fat and non-fat tissue in T1W TSE images is sometimes not sharp enough to differentiate fat reliably, especially when it is desired to use automatic or semi-automatic computer programs for fast post-processing. Recently, a water-suppressed T1W-TSE ((WS T1W TSE) sequence was reported to offer reduced flow artifacts and greatly improved CNR between fat and lean-tissue, which makes fat quantification much easier and more reliable (1). We have recently reported that a 3D water-saturated, balanced steady-state free-precession (WS b-SSFP) sequence can provide much higher acquisition bandwidth (BW) along frequency- and phase-encoding directions, thereby minimizing scan time, as well as offering a high SNR and CNR (2). In (2), SNR and CNR performance of this sequence for human abdominal fat imaging were compared with that of a traditional non-water-suppressed T1W TSE sequence, which is commonly used in the clinical environment. What is not known, however, is the SNR and CNR performance of WS b-SSFP compared with a WS T1W-TSE sequence. In this article we will compare the SNR and CNR performance of WS b-SSFP with that of a WS T1W-TSE sequence.

Methods

6 healthy volunteers underwent abdomen imaging in a 1.5 T clinical MR scanner with 33 mT/m, 120 T/m/s performance (Philips Gyroscan Intera, Release 10.3) using a standard quadrature-body coil. A clinically available magnetization prepared, segmented, 3D b-SSFP sequence (b-TFE) was employed. To achieve water saturation instead of fat saturation as the default, the synthesizer frequency was first shifted to resonant frequency of fat (a shift of -220Hz) before 3D WS b-SSFP scans were acquired. The SPIR pulse had a flip angle of 120°, a bandwidth of 340 Hz, and the frequency was manually shifted from -260 Hz to +310 Hz for water-saturation. The signal contribution from the T_1-recovered magnetization from water was minimized by using a center-out profile order along phase-encoding direction, and a linear phase encoding in the slice-encoding direction. Other parameters included: TR/TE/FA=2.9ms/1.2ms/55° with partial-echo readout of 62.5%, ETL=128 with $\alpha/2$ preparation and 12 dummy echoes, readout bandwidth =200kHz, FOV=400~480mm, MS=256×256, slice thickness=10 mm. Readout direction was anterior-posterior to minimize respiratory motion artifacts. 8 axial slices were obtained in the abdomen centered at L2~L3 level and the total scan duration was 11 seconds. WS T1W TSE was also performed with TR/TE/FA=500ms/5ms/90°, turbo factor=7 and readout bandwidth=128 kHz. 6 slices (corresponding to the position of slice 2 to 7 in WS b-SSFP sequence) were obtained. Both WS b-SSFP and WS T1W TSE were imaged with breath-hold to reduce motion artifacts. Image processing was accomplished using in-house programs written in IDL. Fat, muscle, and bowel content signals (S_{fat}, S_{muscle}, and S_{bowel}) were measured on hand-drawn ROIs. Noise (σ_n) was estimated from the background air anterolateral to the anterior chest wall. The SNR and CNR were defined as follows: $SNR_{fat}=S_{fat}/\sigma_n$, $CNR_{fat\text{-}muscle}=(S_{fat}-S_{muscle})/\sigma_n$, $CNR_{fat\text{-}bowel}=(S_{fat}-S_{bowel})/\sigma_n$. SNR and CNR of each of the 6 common slices of both techniques on every subject were calculated and averaged respectively to obtain the overall SNR and CNR for the subject, leading to 6 datasets for each technique. A two-tailed paired sample t-test was then performed to determine the statistical significance of SNR and CNR differences between images obtained by the two sequences. A P value of less than 0.05 was considered as statistically significant.

Results

Example images of WS T1W TSE and WS b-SSFP are shown in Fig. 1. WS TSE images (Fig. 1a) tend to suffer from slight motion artifacts due to bowel motion and residual respiration. No obvious motion-induced artifacts were noticed on WS b-SSFP images (Fig. 1b) as imaging bandwidth along phase-encoding directions is high. WS b-SSFP images, however, suffer slightly from transient effects of off-resonant fat spins. SNR and CNR results on hand-drawn ROIs are shown in Table. 1. SNR_{fat}, $CNR_{fat\text{-}muscle}$, and $CNR_{fat\text{-}bowel}$ of WS b-SSFP are significantly higher than that of WS T1W TSE (all $P<0.005$), with the improvement being 21.2%, 24.5%, and 31.3%, respectively.

Discussion

Employing water suppression/saturation techniques can greatly improve the CNR between fat and lean-tissues. However, SNR of the resultant images will be compromised when compared to corresponding non-water-suppressed sequences since a large portion of spins (water magnetizations) are suppressed. In the case of non-water-suppressed T1W TSE reported in (2), SNR_{fat} decreases from 108 to 85.2 (23.6%) after employing water-suppression. WS b-SSFP, however, can provide superior SNR and CNR over WS T1W TSE due to the inherent high SNR property of coherent imaging, even though higher readout bandwidth and partial-Fourier acquisition are employed (2). B-SSFP is particularly suitable for fat imaging due to the fact that b-SSFP is T_2/T_1-weighted, and fat has a longer T_2 and shorter T_1 than most stationary non-fat tissues. The ultra-short TR (2.9ms) increases SNR, decreases total scan duration, and minimizes the motion-induced artifacts that complicate abdominal imaging. Therefore, WS b-SSFP is preferable for fat imaging using MRI compared to WS T1W TSE.

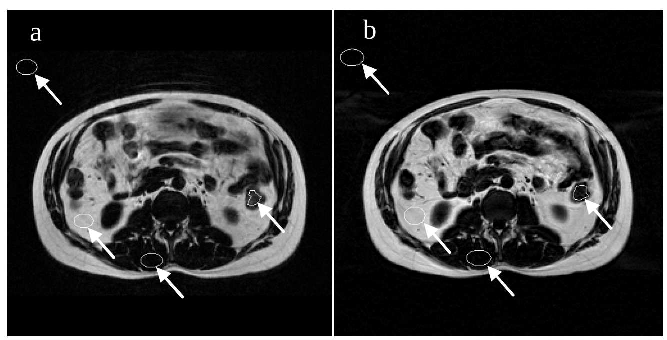

Fig. 1. (a): Water-suppressed T1W TSE. (b): Water-Saturated b-SSFP at the same slice position. Examples of ROI contours are also shown in the two images (arrows).

References

1. Tintera J, Harantova P, et al, Physiol Res 2004; 45: 1075-80.
2. Peng Q, McColl R, et al, JMRI, 2005 (in press).

Table. 1. SNR and CNR Comparison between WS T1W TSE and WS b-SSFP (n=6)

Subject	SNR_{fat}		$CNR_{fat\text{-}muscle}$		$CNR_{fat\text{-}bowel}$	
	WS T1W TSE	WS b-SSFP	WS T1W TSE	WS b-SSFP	WS T1W TSE	WS b-SSFP
A	91.3	105.5	87.0	103.3	82.4	100.8
B	95.9	121.0	91.5	117.3	87.2	115.3
C	80.3	110.2	75.9	107.5	70.4	103.6
D	88.5	96.7	83.5	93.2	68.9	89.8
E	77.6	96.6	74.8	94.8	70.5	91.6
F	77.2	89.8	71.6	86.7	65.9	83.2
Mean±SD	85.2±7.9	103.3±11.3	80.7±7.8	100.5±11.1	74.2±8.5	97.4±11.5
P	0.0028		0.0017		0.0003	