CT vs. WS b-SSFP (MRI) for Body Fat Quantification: A Phantom Study

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Introduction

Human body fat imaging and its quantification is of great importance since excessive accumulation of regional adipose tissue is widely regarded as a sign of diseases such as non-insulin-dependent diabetes mellitus, cardiovascular disease, and cancer. Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI) are the two imaging modalities widely used for human body composition studies. CT is known to provide a faster and a more accurate quantification of fat quantification compared to traditional MRI techniques, especially for abdominal fat imaging. With the development of new MRI technologies, a new fast fat imaging sequence, water-saturated balanced steady-state free precession (WS b-SSFP) has been proposed (1). It has been shown that the fat quantification accuracy on a phantom using WS b-SSFP is greatly improved compared with that of a traditional T1W TSE sequence (1). It is however unknown what the fat quantification accuracy of this new MRI sequence is compared to CT. In this article, fat quantification accuracy using CT and WS b-SSFP is quantitatively compared using the same oil phantom as described in (1).

Methods

The same phantom as described in (1) was employed. This phantom has dual-layered concentric cylinders with internal/external oil volumes of 3.16L/6.34L, simulating an intra-abdominal fat to subcutaneous fat ratio of 0.498. All MR imaging experiments were performed on a 1.5 T clinical MR scanner with 33 mT/m, 120 T/m/s performance (Philips Gyroscan Intera, Release 9.11) and a standard quadrature-body coil was employed. The detailed description of the WS b-SSFP sequence can be found in Phantom Studies in Materials and Methods of (1). The same sequence was repeated three times over three days. CT scans were made in the same phantom on a GE Lightspeed16 CT scanner operating in axial mode with the following parameters: 140kvp, 250mA, exposure time 1s, and FOV=400mm. As in WS b-SSFP situation, the phantom was imaged three times. For both MRI and CT, the resultant images were processed twice, as described below, to get 6 data points of internal, external, total oil volumes, and internal/external oil volume ratio. Both MRI and CT resultant images were processed using a semi-automatic computer software developed in-house. The details of software and the oil volume calculation using this software are described in (1). Briefly, the user is required to choose a threshold to differentiate water from fat. A single factor analysis of variance (Anova) was used to determine whether the two techniques predicted significantly different oil volumes and ratios. A P value of less than 0.05 was considered statistically significant.

Results

Example images obtained using CT and WS b-SSFP are shown in Fig. 1. As CT can only capture the density of the imaged object, oil, as well as phantom materials (tubes) are shown in the resultant image (Fig. 1a). WS b-SSFP, however, is only sensitive to hydrogen spins, and since water spins are effectively saturated, fat-/oil-only images are obtained (Fig. 1b).

The measured oil volumes/ratios are shown in Table. 1 as the percentage of the corresponding true volumes or ratio. Both techniques provided very accurate predictions (error≤1.5%). There is no statistical difference for internal and total volume predictions between the two modalities. The external oil volume, and internal/external oil volume ratio, however, are significantly different, although this difference is very small (1.2% and 1.7%, respectively). CT also provided a very accurate internal/external oil volume ratio (100.2%).

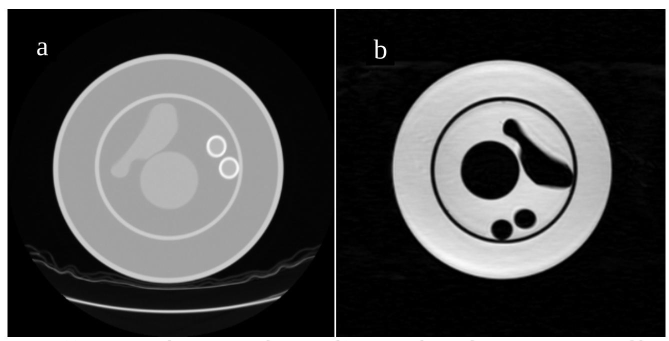

Fig. 1. (a): CT example image on phantom. (b): Image obtained using water saturated b-SSFP (MRI) at the same slice position.

Discussion

CT is not preferable for fat quantification in the clinical environment due to the associated radiation exposure. It is especially not suitable for repeated studies of infants, children, and healthy subjects. It has been demonstrated in this study in phantoms that both CT and MRI (using WS b-SSFP) can provide accurate oil volume/ratio estimation. CT provides a more accurate internal/external oil volume ratio because any systematic geometric error of CT is corrected in the ratio calculation. WS b-SSFP provides slight under-estimation of internal oil volume, and slight over-estimation of external oil volume due to B_0 inhomogeneity and gradient non-linearity. The estimation error is, however, very small (≤1.5%).

In human studies, the fast speed of CT may lead to more accurate fat quantification for intra-abdominal fat, as it is less sensitive to motion-induced errors. The disadvantage of CT is that, the signal intensity of fat is low, close to that of air and bowel gas. This may potentially lead to fat quantification error. It is also important to note that WS b-SSFP can provide fat-only images without the need of further image post-processing, and lends this technique to much easier fat quantification using automatic or semi-automatic fat quantification than CT.

References

1. Peng Q, McColl R, et al, JMRI, 2005 (in press).
2. Scheffler K, Lehnhardt S, Euro Radiol 2003; 23: 2409-18.

Table 1. Comparison of Phantom Oil Volume Measured Using CT and Water-saturated b-SSFP of MRI (n = 6)

Repeat #	Internal Oil (%)*		External Oil (%)		Total Oil (%)		Intern-/External Ratio (%)	
	CT	b-SSFP	CT	b-SSFP	CT	b-SSFP	CT	b-SSFP
1	100.3	99.7	99.7	100.7	99.9	100.4	100.6	99.0
2	99.7	98.5	99.4	100.3	99.5	99.7	100.3	98.2
3	98.7	98.1	99.2	100.5	99.1	99.7	99.5	97.6
4	100.0	99.8	99.7	100.9	99.8	100.5	100.3	99.0
5	98.7	100.8	99.1	101.2	98.9	101.1	99.7	99.6
6	100.3	97.5	99.5	100.2	99.8	99.3	100.8	97.4
Mean±SD	99.6±0.7	99.1±1.2	99.4±0.3	100.6±0.4	99.5±0.4	100.1±0.7	100.2±0.5	98.5±0.9
P	0.373		<0.0001		0.081		0.002	

*: All measurements are shown as the percentage of the corresponding true oil volume or ratio.