Intrinsic Water-Suppression in TIDE-bSSFP Applied for Quantification and Differentiation of Adipose Tissue

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Introduction:

The amount of adipose tissue and especially its localization to the visceral compartment is an important risk factor for cardiovascular and metabolic diseases. Among numerous measurement techniques, MRI stands out due to its ability to determine the distribution of visceral and subcutaneous fat reliably without radiation exposure [1]. Powerful and elaborate MRI methods for fat-water-separation are available that are mostly based on metabolite specific pre-saturation and chemical shift encoding [2,3]. However, studies that investigate fat distribution in larger patient samples commonly prefer simple and fast techniques like T1-weighted imaging that are less complex with respect to data acquisition, processing, and evaluation [4,5]. In this context, the inherently bright fat-signal in bSSFP sequences (balanced Steady State Free Precession) may offer promising options. Particularly in combination with the intrinsic effects of FS-TIDE (Fat Suppressed-Transition into Driven Equilibrium) [6,7], fast chemical-shift selective data acquisition may be achievable. This work introduces intrinsic water suppressed TIDE-imaging (WS-TIDE) in vivo and gives an estimate on its applicability as a tool for adipose tissue quantification in obese patients.

Method:

TIDE sequences apply a variable flip angle scheme (Fig 1A) that forces a change in signal behavior from a TSE (Turbo-Spin-Echo)-like mode to the bSSFP mode (Fig 1B). During this transition, the signal from off-resonant spins undergoes a zero crossing (Fig 1C). Intrinsic water suppression is achieved by setting the scanner's resonance frequency to the Larmor frequency of fat and sampling k-space center coincidentally with the zero crossing of the off resonant water signal (Fig 1D). Due to the early zero crossing a Partial Fourier data acquisition with linear reordering was used. WS-TIDE was tested in phantoms and healthy normal weight volunteers. Sequence parameters: TR/TE=4.34/2.17 ms, matrix=256x208, FOV=450x366 mm^2, slice thickness=8 mm, scan time per slice=0.6 s. TIDE-parameters: FAmax=180°, FAmin=60°, ramp length=24. Imaging was performed on a 1.5 T wide bore (Ø=70 cm) clinical MR system (Magnetom Espree, Siemens Medical Solutions, Erlangen, Germany) with TIM multi channel whole body coverage surface coils. Segmentation was done using thresholding and region-growing procedures in MATLAB (the MathWorks Inc., Natick, MA, USA).

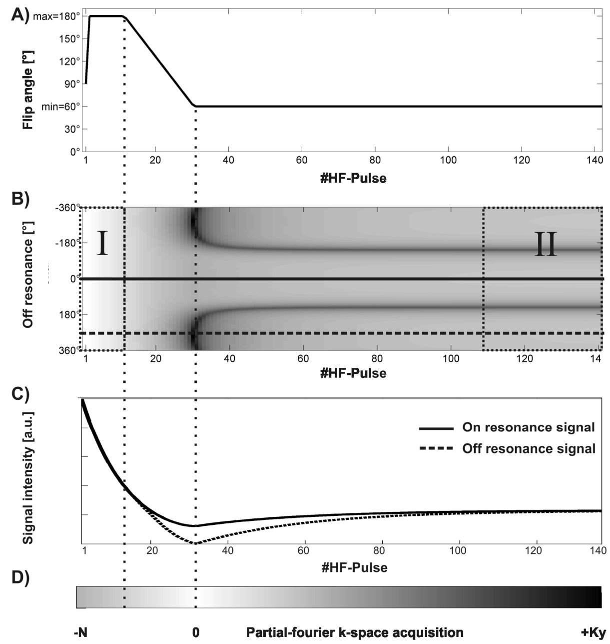

Fig 1: Principle of intrinsic water suppression with TIDE: A) flip angle scheme; B) signal behavior (simulation), I=TSE-like mode, II=bSSPP-mode: Note the simultaneous appearance of the stop bands over wide frequency bands; C) signal behavior (cross section from B), dashed curve: off-resonance signal (water), solid curve: on resonant signal (fat); D) k-space sampling pattern.

Results and Discussion:

Phantom and in vivo experiments revealed the following beneficial properties of WS-TIDE for adipose tissue quantification: 1) Fast and stable image data acquisition; 2) Excellent water signal suppression without additional complexity or increased scan time; 3) Very high fat signal (SNR ≈ 25.5) and fat/muscle contrast (CNR ≈24); 4) High stability to breathing motion; 5) Data can be segmented fast and easily. Adverse effects to consider are: 1) Sensitivity to blood flow in the great vessels. This may be compensated by spatial suppression pulses; 2) Banding artifacts at the periphery of the FOV due to B0-inhomogeneities (wide bore and large patient size). This effect is lowest in axial single slice 2D imaging; 3) Structures with very long T2 (filled urinary bladder) may experience insufficient water suppression. This demands for specific patient preparation. In conclusion, water suppressed WS-TIDE imaging combines the intrinsic properties of TIDE and standard bSSFP into a powerful tool for fast and simple quantification of adipose tissue. Among technical refinement, ongoing investigation will address clinical evaluation of WS-TIDE in obese patients along with a detailed comparison to standard fat quantification techniques.

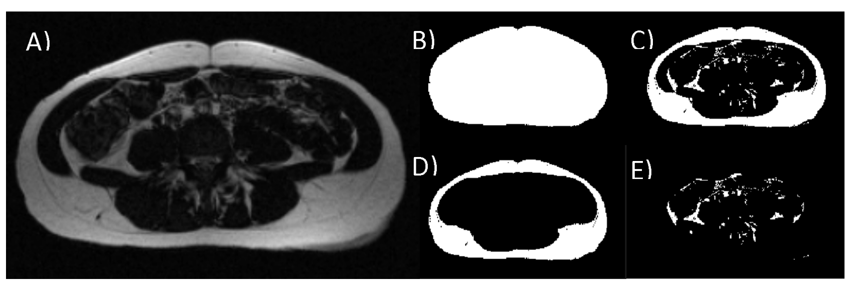

Fig 2: Example images from a female normal weight volunteer (BMI≈21 kg/m^2) at L 4/5: A) original image data, B) total slice volume (=100%), C) total fat volume (=40%), D) subcutaneous fat volume (=36%), E) visceral fat volume (=4%).

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