3D Double Echo TrueFISP and FLASH Ultra-short Echo Time Musculoskeletal Imaging

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Introduction

Ultra-short Echo Time (UTE) MRI allows for the detection of short T2 components (T2 of the order of 100 µs) in tissue before they have decayed [1, 2]. This is potentially interesting for a range of applications such as MR imaging of bone, tendons and ligaments, sodium MRI, and other applications such as MR-PET attenuation correction.

Until now the UTE method has been based on a Steady State Free Precession (SSFP) sequence with Fast Low Angle Shot (FLASH) contrast [2] where, an excitation pulse α tips the magnetization M_0 so that the transverse component $M_t=M_0\sin\alpha$ can be measured and, after the readout gradient, is spoiled through gradient and RF spoiling, so that only the longitudinal component $M_l=M_0\cos\alpha$ is available for the next excitation. This FLASH technique suffers from two main disadvantages: low signal-to-noise ratio (SNR) and low contrast. These two drawbacks, together with the fact that the ultra short T2 signal is intrinsically low, compromise the image quality and diagnostic relevance of this technique. Balanced Steady State Free Precession (b-SSFP, also known as TrueFISP, FIESTA, and balanced FFE) [4, 5] is an SSFP technique in which the magnetization M_t is preserved by applying fully compensated gradients that null the zeroth moment between RF-pulses. TrueFISP provides a different contrast and higher SNR and, due to the fact that the gradients are fully compensated, TrueFISP is inherently less sensitive to eddy currents than FLASH.

The UTE signal decays with ultra-short T2. This means that, for TrueFISP acquisitions, M_t will only be preserved from RF excitation to RF excitation if the repetition time (TR) is very short (TR≤T2). Therefore, as long as TR>T2, the behavior and intensity of the UTE signal should be identical for TrueFISP and FLASH acquisitions. On the other hand, fast readouts are required to better describe the UTE signal decay. For such high bandwidths (BW) and short TRs, TrueFISP images will have a sharper point-spread-function than FLASH images due to their insensitivity to eddy currents, leading to increased SNR.

Materials and Methods

The 3D radial multi-echo UTE sequence and reconstruction algorithm were implemented on a 1.5 T clinical scanner (MAGNETOM Avanto, Siemens AG HCS, Erlangen, Germany). It consists of a 60µs long non-selective RF pulse followed by a 40µs transmit/receive switch time and a 100% asymmetric data acquisition from the centre to the surface of a sphere. In order to achieve the shortest possible TE, data acquisition starts during ramp-up time of the readout gradient. The online reconstruction program consists of a Kaiser-Bessel Gridding algorithm (window width = 3 and β = 4.2054) with sampling density compensation modified to correct for undersampling. Foam phantom experiments were performed to determine the SNR increase between FLASH and TrueFISP for the same sequence parameters (TR = 3.1 ms, TE=0.07, α = 15°, BW = 5210 Hz/pixel). The following sequence parameters were used for volunteer examinations of the head: TR = 4.1 ms, double echo TE=0.07 and 2.67 ms, α = 15°, BW = 1149 Hz/pixel, 64000 projections, Tacq= 4 min).

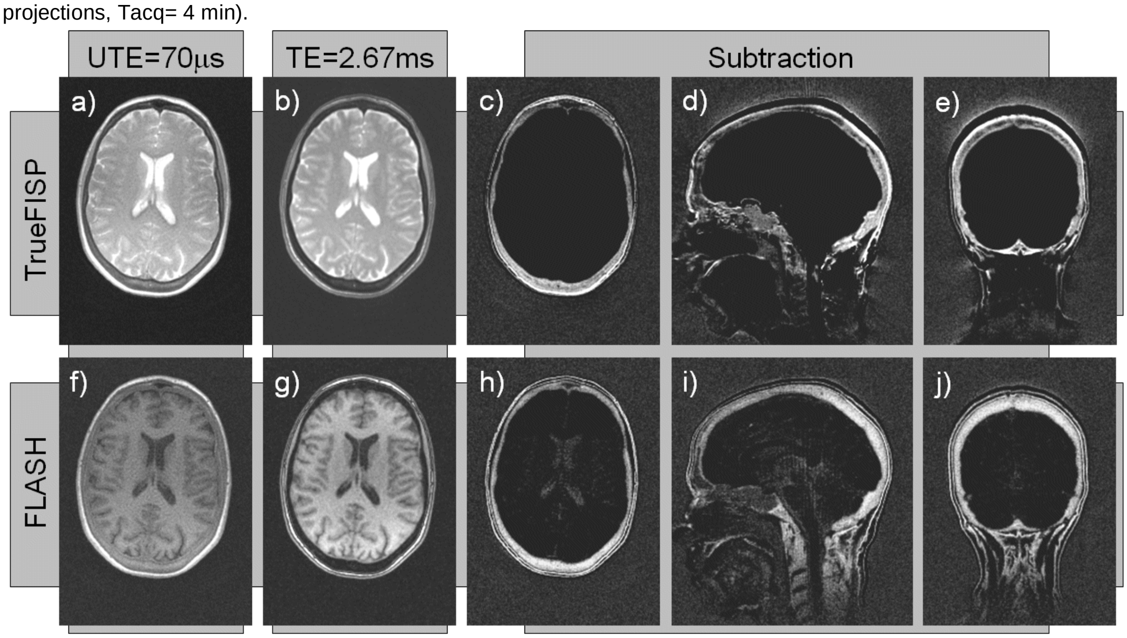

Figure 1

TrueFISP (a, b, c, d, e) and FLASH (f, g, h, i, j) images of the head of a healthy volunteer and their corresponding subtractions. The transversal, coronal and sagittal cuts of the subtraction data set show the 1 mm isotropic resolution of the data. While both FLASH and TrueFISP subtraction images depict the hard tissue, the delineation of the bone appears much more precise in the TrueFISP subtraction images.

Results

In the foam phantom experiments the TrueFISP images showed up to 1.6 times higher SNR than the FLASH images with identical acquisition time and geometry. The SNR gain of TrueFISP versus FLASH increased with higher BW and shorter TR. Figure 1 shows TrueFISP (a,b) and FLASH (f,g) UTE and echo images of the head of a healthy volunteer and their corresponding subtractions (TrueFisp c,d,e; FLASH h,i,j). The transversal, coronal and sagittal cuts of the subtraction data sets show the 1mm isotropic resolution of the data. While both FLASH and TrueFISP subtraction images depict the hard tissue, the delineation of the bone appears much more precise in the TrueFISP subtraction images.

Discussion

The feasibility of multi-echo TrueFISP UTE Imaging has been demonstrated. Preliminary results of 3D TrueFISP UTE and 3D FLASH UTE images of the head have been shown. The results demonstrate that a 3D TrueFISP UTE acquisition would provide significantly increased contrast, SNR and less sensitivity to eddy currents than a FLASH UTE acquisition. The delineation of the bone is much more precise in the TrueFISP subtraction image for identical acquisition time and geometry, showing great potential for further development of the technique in applications such as musculoskeletal imaging, MR-PET attenuation correction, radiotherapy attenuation correction and sodium imaging.

References

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