T_2*-based Fat-Water separation

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Introduction

Separation of fat and water signals has many applications, e.g. fat suppression in MR images or imaging of total body fat and its distribution in studies of human body composition. The chemical shift, i.e. the frequency shift of CH_2 protons in fat of about -210 Hz at 1.5 T, enables separation of the two signals by means of a two point spectroscopy [1]. In the presence of main field inhomogeneities, at least three echoes must be sampled to take the additional B_0 dependent phase shift into account [2]. Calculation of in vivo B_0 fieldmaps involves phase unwrapping procedures to remove 2π ambiguities in the phase difference maps. These algorithms are computationally intense and in general not failsafe. Here we present a simple and fast approach for fat/water imaging based on the different transverse relaxation behavior of the two components.

Materials and Methods

All studies were performed at 1.5 T on a Siemens Magnetom Sonata system. Our method makes use of a feature that is unique to fat: the pronounced biexponential signal decay resulting from the considerable proportion of fat protons with very short transverse relaxation times (α-and allylic protons) [3]. Three in-phase images were acquired per slice at echo times of 4.76 (TE_0), 9.53 (TE_1) and 14.3 (TE_2) ms using a spoiled gradient echo sequence with multi-echo readout after each excitation. The signal F proportional to the fat content was computed: $F = S(TE_0) - S(TE_1)\cdot S(TE_1)/S(TE_2)$. F is the deviation of the signal $S(TE_0)$ from the mono-exponential decay in the rest of the echo series. The same sequence was measured for comparison using echo times of 4.76, 7.15 and 9.53 ms (in-phase and opposed phase) to allow for a three-point Dixon decomposition. All images had coronal orientation and a 500 mm FOV so that phase unwrapping was necessary when using the Dixon technique. A 3D quality guided path following algorithm was implemented for that purpose.

Results and Discussion

With the presented technique it was possible to generate fat and water images. There is a clear biexponential T_2* decay of transverse fat proton magnetization. The magnitude ratio of the first two in-phase echoes in subcutaneous fat was 1.77 whereas it was 1.03 between the second and third echo. As can be seen in figure 1, fat and water images computed with our method have lower SNR values than those from the Dixon decomposition. However, the Dixon phase unwrapping took about 3 minutes for 25 slices and did not remove the phase jumps completely. If more than the minimum of 3 echoes is sampled for an increased SNR anyway [4], our method generates supplementary fat and water images. It is also possible to include the T_2* based decomposition into a phase unwrapping algorithm as a likelihood criterion. The biexponential signal decay must be considered in the Dixon decomposition of the first echoes as well; otherwise about 10% of the fat signal appears in the water image.

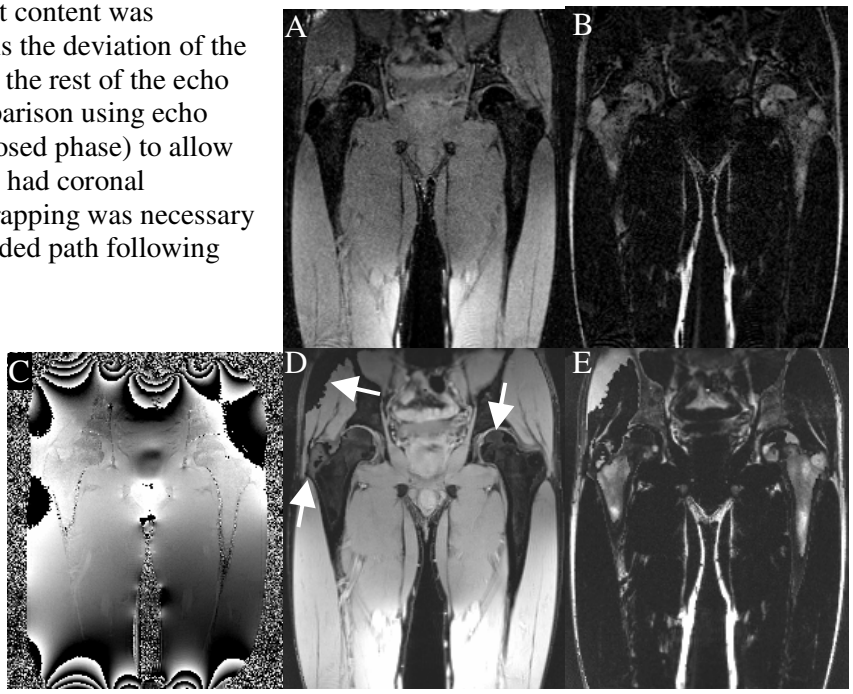

Figure 1: Coronal images acquired using the two techniques: water and fat decomposition based on T_2* separation (A, B) and using three-point Dixon decomposition (D, E). Unwrapping of the phase difference map (C) left some residual 2π jumps, resulting in an exchange of water and fat in the images (arrows). The best approximation of the water signal at TE_0 (A) was found to be: $W = S(TE_0)-2.3\cdot F$.

References
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