Three-point Dixon method for whole-body water/fat imaging

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Introduction Dixon methods [1-5] separate the MR signal from different chemical species with respect to chemical shift. The most common application is water-fat imaging. Three-dimensional whole-body water and fat images form a valuable tool for measuring body composition. However, existing three-point methods such as IDEAL [2,3], are not intended for whole-body datasets. Problems typically encountered are shown in fig. 1. In this work, a method is proposed that is suitable for whole-body datasets, by utilizing 3D information, being robust against strong B0 inhomogeneity, and being computationally efficient.

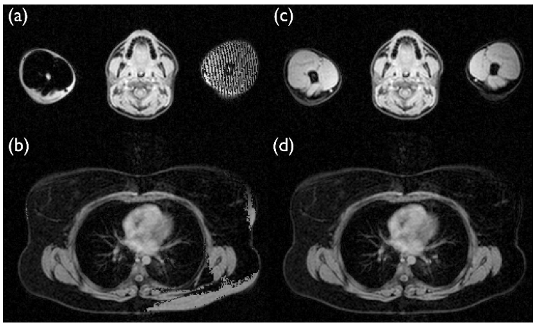

Fig. 1. (a,b): Water image produced by IDEAL [2] with the proposed region growing scheme [3]. This scheme uses only one seed point in each slice, which causes errors when tissues are separated by noise (a). Due to its predestinated path, the region growing may propagate through noisy regions, such as the lungs (b), causing errors even when tissues are connected. Water image of the same slices produced by the proposed method is shown in (c) and (d).

Methods Three complex source images are acquired with any constant echo time spacing in a multi-gradient-echo sequence. A simple signal model is used, taking into account the known chemical shift between water and fat, the unknown water and fat signals, and an additional unknown phase vector (mainly due to B0 inhomogeneity). Two alternative phase vectors can be found analytically in each voxel. The "false" phase vector satisfies the signal model if the water and fat signals are swapped. For voxels with sufficient amounts of both water and fat, the true phase vector can be identified as the one giving the smallest phase discrepancy between the water and fat signals [4]. All such voxels serve as seed points in a 3D region growing scheme, imposing smoothness of the phase vector field. A dynamic region growing path, similiar to the approach in [5], allows confident regions to be grown before unconfident regions, such as background noise. When the phase vector field is determined, the least-squares solution of the water and fat signals can be found in each voxel.

A Philips 1.5 T Achieva scanner equipped with a continously moving bed (COMBI), was used to collect whole-body datasets (256×184×252 voxels with size 2.1×2.1×8.0 mm^3) from 39 volunteer subjects with BMI 19.8–45.4 kg/m^2, of which 10 were normal weight (BMI<25), 12 were overweight (25≤BMI<30), and 17 were obese (BMI≥30). The body coil was used for RF transmission and signal reception. A 3D gradient echo sequence was used with EPI readout (using the same readout gradient polarity). The echo times were TE1=1.36 ms and ΔTE=1.86 ms, and the total scan time was 5 min 15 s. Each stack in the whole-body datasets was processed separately to obtain water and fat images as described above. The resulting images were inspected by two radiologists, instructed to subjectively grade the amount of water-fat swap-artifacts on a four-grade scale. The grades were defined as: *poor* = severe swap-artifacts, *fair* = moderate swap-artifacts, *good* = mild swap-artifacts, *excellent* = no visible swap-artifacts. In each subject, five body regions were graded: head and arms, thorax, abdomen, pelvis, and legs.

Fig. 2. Water and fat images of the whole body from one normal weight (BMI 24.3) and one obese subject (BMI 40.7).

Results Water and fat images were sucessfully derived from all the whole-body datasets using a standard laptop computer, with a mean processing time of 1 min 51 s, corresponding to <0.5 s for a 256×184 slice. The grading results are given in table 1. The two best grades were received exclusively, impying that only mild reconstruction failures were found. Examples of water and fat images are shown in fig. 2.

	poor	*fair*	*good*	*excellent*
Head&arms	0 | 0	0 | 0	22 | 2	17 | 37
Thorax	0 | 0	0 | 0	3 | 1	36 | 38
Abdomen	0 | 0	0 | 0	9 | 0	30 | 39
Pelvis	0 | 0	0 | 0	2 | 1	37 | 38
Legs	0 | 0	0 | 0	2 | 0	37 | 39

Tab. 1. Frequency of grades in the different body regions of the 39 subjects. The frequencies from the two readers are separated by |.

Conclusion The proposed method offers fast and accurate whole-body water and fat imaging with few or no swap-artifacts, even for obese subjects. Echo times are flexible, and phase unwrapping is not needed.

References 1. Dixon WT. Radiology 1984;153:189-94. 2. Reeder SB, et al. Magn Reson Med 2004;51:35-45. 3. Yu H, et al. Magn Reson Med 2005;54:1032-9. 4. Xiang QS, An L. J Magn Reson Imaging 1997;7:1002-15. 5. Ma J. Magn Reson Med 2004;52:415-9.