Virtual Phantom (ViP) MRI: a method to generate virtual phantoms that mimic water-fat systems

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Introduction: Virtual Phantom[1] (ViP) for Magnetic Resonance Imaging (MRI) is a method to generate reference signals, without using physical objects. This method represents the extension of the ERETIC method (largely used in spectroscopy[2,3]) to MRI. ViP MRI works as follows: given a numerical phantom (in k-space representation), a waveform generator converts the k-space lines into a radiofrequency signal (ViP signal) that is transmitted to the MRI scanner by an RF coil. The MRI scanner records the ViP signal simultaneously as the signal from the object of interest (**Fig. 1**). In the previous work it was shown that ViP MRI could substitute agar gel phantoms, using magnitude images. The aim of the current study is to test the feasibility of the ViP MRI method to generate magnitude and phase images that mimic water-fat systems. To this aim, multi gradient-echo magnitude and phase images of ViPs and physical phantoms were acquired for IDEAL[4] (Iterative Decomposition with Echo Asymmetry and Least squares estimation) reconstruction.

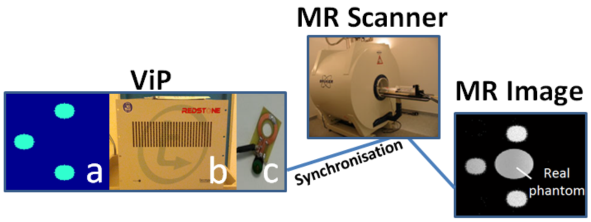

Fig. 1: Schematic of the ViP MRI method: the ViP apparatus (first box) consists of **a)** numerical phantom **b)** a waveform generator and **c)** an RF coil, located within the MR scanner bore. The ViP apparatus works in synchronization with the MR scanner (second box) for generating an MR image (third box)

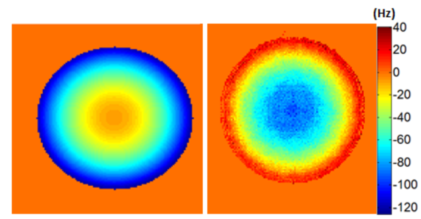

Fig. 2: Field maps of the circular phantom calculated with IDEAL: on the left calculated with the simulated data and on the right with the experimental data.

Materials and methods: A program in MATLAB® which permits to simulate MR signals was elaborated: this program allows to choose fat fraction percentage, echo times, number of echoes and spin-spin relaxation time (T2*) for each phantom and create a field map of arbitrary shape. Simulated images were converted in k-space representations, transformed in RF amplitude and phase for the waveform generator (Redstone Tecmag Inc. Houston TX, USA) and transmitted to the MRI scanner by an RF coil. Simulated images parameters were as follows: T2* = 20ms; TEs =1.4, 3.8, 6.2 and 8.6 ms. Two phantoms were designed: 1) a circular ViP and a parabolic-shaped field map to test the ability to reproduce well the phase maps; 2) three small circular ViPs with a different fat fraction (10% 20% and 30%) to test the feasibility of the ViP MRI to mimic water-fat systems. MRI measurements were performed at 4.7T (47/40 Bruker Biospec). Multi gradient-echo images were acquired with the same TEs of the simulated images, dwell time= 6.6µs, matrix size 128x128, field of view = 3x3 cm^2. All simulated and experimental data were processed with a homemade script in MATLAB® which implements the IDEAL algorithm.

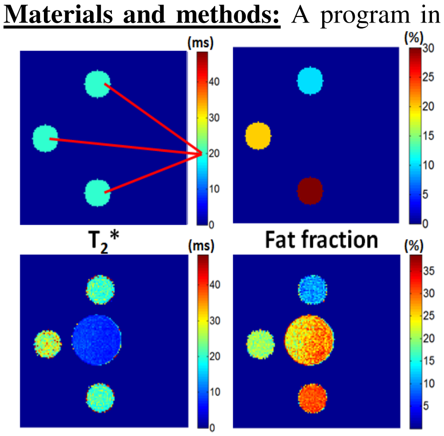

Fig. 3: On top the results of IDEAL relative to the simulated data and below for the experimental data: T2* (left) and fat fraction map (right). In the experimental results is shown the real tube as well

Results: In **Fig. 2** the field maps relative to the first phantom, calculated with IDEAL, are displayed: the field map calculated from the experimental data was in good agreement with the simulated one. The experimental field map well reproduced the parabolic shape of the simulated one, with a similar range of values. In **Fig. 3** there are shown the outputs of IDEAL for the second phantom. During the acquisition of the second ViP, a physical phantom containing full cream was also employed. ROI measurements were obtained on ViPs of the experimental images in **Fig. 3**. Means and standard deviations extracted on fat fraction map were 10.5 ± 1.9%, 20.3 ± 1.6% and 30.4 ± 1.2% and, on T2* map, 20.6 ± 2.6ms, 26.5 ± 4.1ms and 21.2 ± 1.2ms, respectively. Good agreement was achieved between simulated and experimental results.

Conclusion: The results of the current study indicate that the ViP MRI method can generate virtual phantoms that mimic water-fat systems, with the use of magnitude and phase images.

Reference

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