SINGLE ACQUISITION FAT WATER SEPARATION USING A GOLDEN RATIO RADIAL BSSFP SEQUENCE WITH DYNAMIC ECHOTIME SHIFTING

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Target audience: Physicists, clinicians

Purpose: Common Dixon-type three-point methods achieve robust fat-water separation, even in the presence of field-inhomogenities[1]. However, these methods need to acquire three complete images, resulting in a triple scan time, which can be problematic in dynamic or breathhold imaging. Other approaches like one-point methods[2] usually require the acquisition of an additional calibration scan for fieldmap estimation.

In this work we propose a new method which allows the extraction of three (and more) images with different echo times out of just one single image without any prescan. These images can then be processed using standard Dixon-type separation techniques.

Methods: We used a modified radial bSSFP sequence with golden-ratio based profile order[3]. Like indicated in figure 1, we changed the echotime dynamically: Starting at TR/2 – ΔTE for the first projection and ending at TR/2 + ΔTE for the last one, the echotime is varied in between by incrementing the position of the readout gradients. Hence, each acquired projection has its own echotime. Afterwards, images with different echotimes can be extracted using a k-space weighted image contrast (KWIC) filter[4] and NUFFT gridding[5].

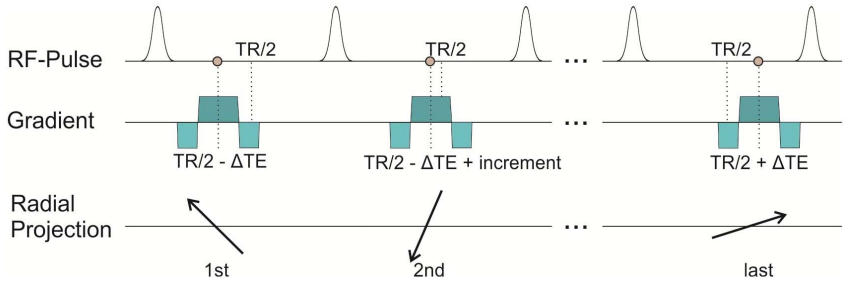

Fig. 1: Illustration of the used bSSFP sequence

In-vivo measurements were performed on a 3.0T clinical scanner (Siemens Skyra) with a 24-channel spine and an 18-channel body array on a healthy volunteer. One single image was obtained using the described sequence with the following parameters: 2D-acquisition, TA=3.5s, 256 readout points, 512 projections, slice thickness=5mm, TR=6ms, ΔTE=0.6ms (resulting in an echotime shift of 2.3µs per projection), flip angle α=40°, FOV=350x350mm², BW=977Hz/px. The KWIC filter was centered at the projections according to echotimes of TE_1=2.4ms, TE_2=3.0ms and TE_3=3.6ms. Fat-Water separation was performed using 3pt Hierarchical IDEAL[6].

To show the possibility to extract more than two chemical species out of one single image, phantom measurements were carried out using the same sequence, now with TR=7.4ms and ΔTE=0.75ms. This time five images were extracted, corresponding to echotimes of TE_1=2.95ms, TE_2=3.37ms, TE_3=3.70ms, TE_4=4.08ms and TE_5=4.45ms. As proof of principle, separation of the different chemical species was performed by matrix inversion.

Results: Figure 2 and 3 show the raw data signal (reconstructed with NUFFT gridding) and the separation results using the proposed technique. For the in-vivo case good fat-water separation is achieved. For the phantom measurement, all three chemical species could be clearly separated. The acquisition time of the data shown was 2/3 of a common 3pt measurement.

Discussion: Further decrease of the acquisition time can be achieved by measuring fewer projections. Of course, this will lead to more streaking artifacts. In this case, parallel MRI may be used to reduce these artifacts. Thus, by simply changing the number of acquired projections, this technique allows for separation of chemical species in a very short acquisition time (at the expense of image quality) as well as separation with high image quality (at the expense of acquisition time). However, one intrinsic drawback of the method is that each reconstructed image combines different echotimes, especially in the outer regions of k-space, resulting in slight blurring of the borders between different species.

Conclusion: We want to note that the method presented here is not a new fat-water separation technique, but a new acquisition scheme to obtain images with different echotimes in a short scantime. The advantage of the proposed technique is that just one data set without prescan must be acquired. Applications like dynamic imaging or breathhold exams could benefit from the proposed acquisition scheme. We showed that it is possible to separate more than two chemical species out of just one image, what can be beneficial for separation of water, fat and silicone in breast imaging.

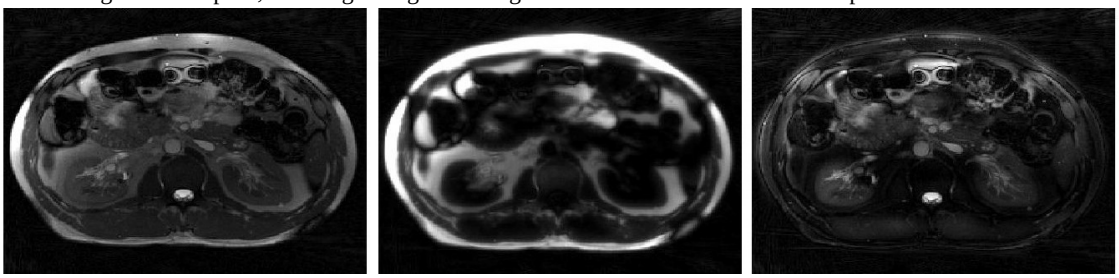

Fig. 2: Raw data signal, separated fat and water

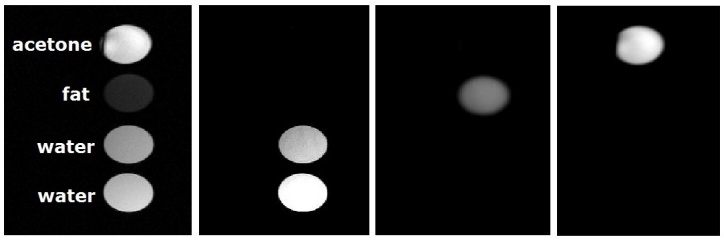

Fig. 3: Raw data signal, separated water, fat and acetone

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