# Faster fat-water imaging with a novel multislice time-shifted GRASE-Dixon sequence.

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**Introduction**

Recently, the gradient- and spin-echo (GRASE) technique has been used to increase efficiency in Dixon fat-water imaging [1,2]. In these sequences, oscillating gradient lobes are carefully positioned between spin refocusing pulses to acquire multiple echoes with the necessary fat-water phase shifts. As it is necessary to collect at least two echoes with approximately π fat-water phase shift between them, the minimum time between refocusing pulses is of the order of 10 ms [1,2]. This determines the minimum acquisition time. Here we show that by using a dual slice spin-echo refocusing technique [3], double-echo GRASE and the two-point Partially-Opposed-Phase Dixon method (POP) [4], we can double the rate at which slices are acquired for Dixon imaging. The non-CPMG condition in Ref [3] is overcome by a novel time-shifting of pulses acting on different slices. Our sequence is similar to the SER-Dixon sequence reported in Ref [5], but Ref [5] did not use a multiple spin-echo train. Morevoer, Ref [5] used a single refocusing pulse acting simultaneously on two slices, which would not be usable in a multiple spin-echo train without violating the CPMG condition.

**Method**

The pulse sequence schematic is shown in Fig. 1. Exc1 and Exc2 are 90° pulses of 1.2 ms duration, separated by 2.3 ms (time for π fat-water phase shift at 1.5T), and modulated to select different slices. Each 90° pulse is refocused by its own 1.2 ms slice selective pulse (Ref1 or 2) after a time τ. The read gradients are adjusted so that each readout lobe encodes an in-phase spin-echo from one slice, and the partially-opposed-phase echo from the other slice; e.g. in Fig. 1, the first readout lobe encodes echoes E2,o and E1,i corresponding to the opposed-phase echo from the second slice and the in-phase echo from the first slice. The second readout encodes echoes E1,o and E2,i which are the opposed-phase echo from slice 1 and the in-phase echo from slice 2. The time between E1,i and E1,o was 1790 us, giving a fat-water angle, $\alpha = 140°$, at 1.5T. The time between E2,i and E2,o was 2810 us, giving $\alpha = 220°$. The time between two echoes in each gradient lobe, e.g. E2,i and E1,o was 510 us. The choice of fat-water angles gives the same effective number of signal averages NSA >1.95 for both slices when reconstructed with the POP algorithm [4]. Note that both slices share the same phase encoding and spoilers. Spoilers were constant throughout the echo train and the same as for a RARE sequence. Also, because spin-echo refocusing reverses the direction of the k-space trajectory, the read gradient polarities need to be reversed after every pair of refocusing pulses. Phase errors due to fast switching of readout gradients were corrected using a separate reference scan as for EPI. As the bandwidth was quite high (1 kHz/pixel), chemical shift misregistration was neglected as a first approximation. The sequence was implemented on an Siemens Sonata 1.5T scanner. In-vivo images were acquired with body and head coils. Scan parameters were: TE = 10.6 ms, ETL = 9, τ = 5300 us, and matrix size per slice = 130 × 128.

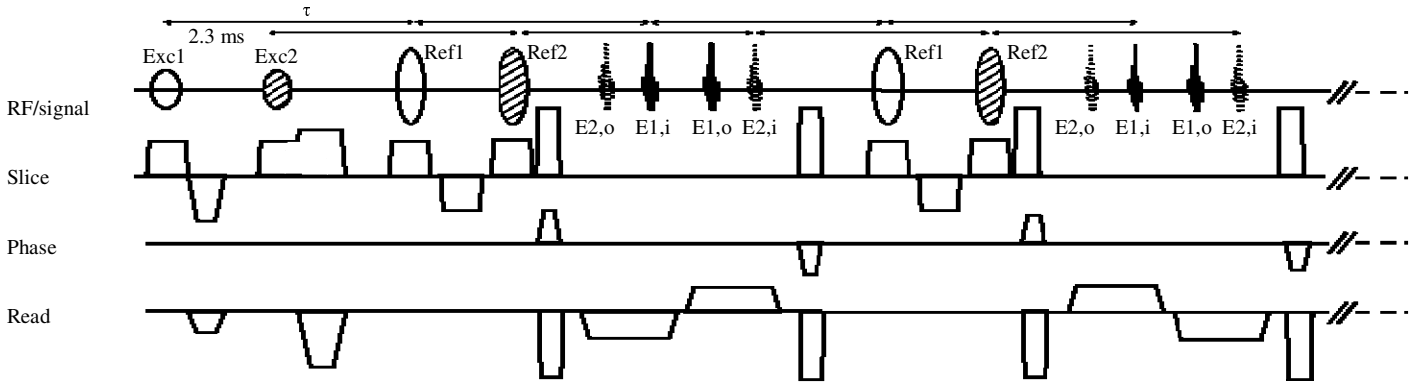


Figure 1. Numbering of RF/signals refer to slice. Index i = in-phase; o = partially-opposed phase. The horizontal arrows at the top are all of equal length τ. Shaded RF pulses and signals correspond to the second slice.

**Results**

The data were divided into two halves in post-processing, corresponding to the slices, and reconstructed with fat-water separation using the POP algorithm as in Ref [5]. Fig. 2 shows in-vivo images from the abdomen and lower leg:

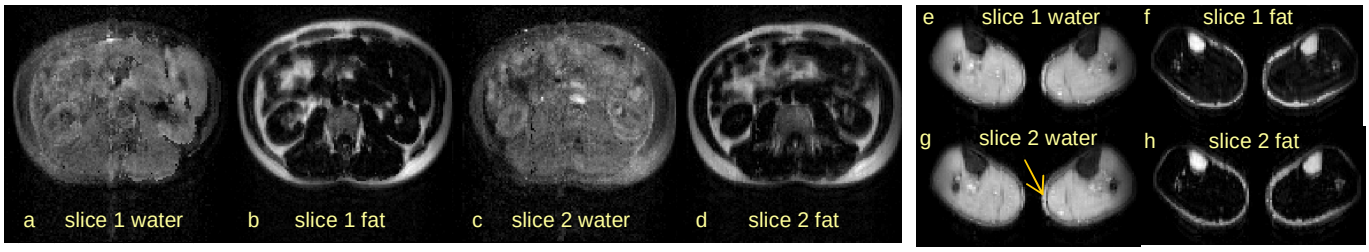


Figure 2. (a-d) Abdominal breath-hold images, body coil, TR = 200 ms, NEX = 3, slice thickness/separation=10/30 mm (e-h) Lower leg, head coil, TR = 3000 ms, NEX = 2, slice thickness/separation = 5/10 mm. Arrow shows an example of misclassification. Read direction is left-right.

**Discussion**

In this sequence, the rate at which slices are collected for GRASE Dixon fat-water imaging is doubled compared with previous implementations. This has been achieved, even though the refocusing pulse spacing is still approximately 10 ms, by (i) using some of the time on one side of the spin-echo from one slice to fit in the refocusing pulse from another slice, and (ii) sharing the time used for spoiling and phase encoding between two slices. By maintaining a constant interval between echo and refocusing pulse for each slice, in theory the CPMG condition is met, thus removing the need for a special spoiler scheme to eliminate stimulated echoes, such as that proposed in Ref [3]. However, in practice, we found that some stimulated echoes were present (data not shown), probably due to imperfect refocusing pulses. This was overcome to some extent by centric phase encode ordering, and acquiring the echoes for the centre of k-space at the beginning of the echo trains. Another artefact arises due to some overlap between high-frequency regions of k-space [5]. This causes crosstalk between slices in fine structures. This is likely to be the cause of misclassification seen at the edges perpendicular to the read direction (arrow in Fig 2). This may be reduced in future by using larger read gradients, or using POMP [6] to separate the slices in the phase encoding direction.

**References**

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