In-vivo water, fat and silicone separation using a fast multi-echo TSE acquisition

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Introduction: Worldwide the number of women with breast implants has been increasing over the last years. These implants, especially if they contain silicone, necessitate regular controls to insure the integrity of the implant and to rule out any ruptures. In clinical routine this is performed using a T2-weighted and a silicone-only image, which is acquired by a combination of an inversion recovery to suppress the fat signal and a silicone only excitation. This has several disadvantages. The silicone only image is not sufficient for a complete diagnosis and an additional T2-weighted sequence is necessary, prolonging the examination time. Furthermore, in the silicone-only images B0 inhomogeneities occasionally cause incomplete fat/water suppression or even signal voids in the silicone, which possibly confound the diagnosis of the implant status. Here the use of a fast Dixon based water, fat and silicone separation is proposed, which ultimately could replace the T2-weighted sequence as well as the silicone only image.

Material and Methods: The data were acquired on a 1.5T scanner (Magnetom Avanto, Siemens healthcare, Erlangen, Germany) using a 2-channel breast coil. To achieve a stable spectral separation of three independent species, 5 echoes were acquired with an echo spacing of ΔTE=2.6ms. To reduce the necessary scantime, the 5 echoes were acquired with bipolar readout gradients within one refocusing interval of a turbo-spin-echo (TSE) sequence (see Fig. 1). The bipolar readout gradients introduce different phase-errors in odd and even echoes. To compensate these phase-errors additional phase correction data are acquired in two additional refocusing intervals after the imaging echo train. These phase correction data acquire 5 times the central *k*-line, i.e. no phase steppers were used, and the second acquisition used inverted readout gradients. Combining each echo pair with reversed polarity, the object phase could be removed from the data and the linear phase error was first fitted and then used to correct the image data. The further sequence parameters were a matrix of 256x256, FoV=350mm, TR=8360ms, TF=8, a bandwidth of 108kHz. Within the total acquisition time of 4.5 min 33 slices with a thickness of 3mm and 10% slice gap covering the whole implant were acquired. The sequence was implemented in the ODIN [1] framework.

For the separation the VARPRO algorithm [2] was used in combination with a region-growing scheme [3] to increase the separation's robustness against B0 inhomogeneities.

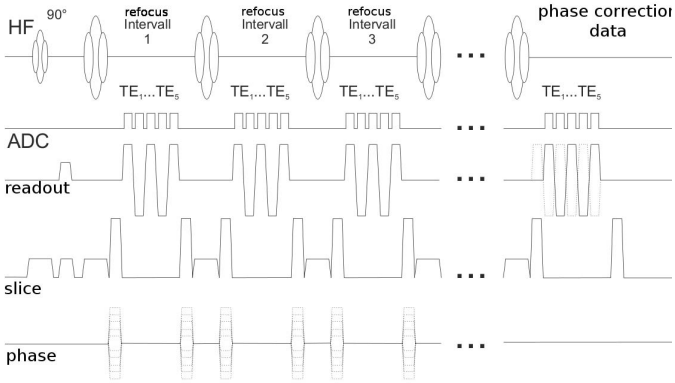

Fig 1: Multiecho TSE sequence sampling 5 echoes with bipolar readout gradients in each refocus interval. A total of 8 k-space lines are acquired for each excitation (TF=8). After the imaging echo train two additional refocusing pulses are used to acquire phase correction data. The second phase correction acquisition uses inverted readout trajectories. This allows to correct the phase error, which is introduced in the imaging data by the bipolar readout gradients.

Results and Discussion: Figure 2 shows the results of the water (a), fat (b) and silicone (c) separation as well as the calculated B0 inhomogeneity map. Due to the age of the patient, there is only very little water signal in the breast itself. The saline solution in the inner volume of the implant is shown with a homogeneous, bright signal. The water signal image also provides a T2-contrast image corresponding to a silicone and fat suppressed T2-weighted image. The weak signal in front of the implant might be due to an inflammatory edema, but with currently only a single case this could also be a separation artifact. The fat component image (b) shows the fat tissue of the breast with rich details and the folds of the implant are also very clearly delineated. Surprisingly, the saline solution shows a signal contribution in the fat image. This could be caused by an imperfect suppression of water signal, which, due to the T2-weighting, is comparatively bright. Further investigations and an extended study on patients are necessary to ascertain if this is indeed an artifact or if it could signify for example the aging of the implant. The silicone only image (c) contains, apart from the clearly delineated silicone shell of the implant, only very low residual signal from other components. The folds of the implant are very clearly delineated in (c). The figures (a) and (b) show the infiltration of water and fat tissue residues into the folds. The diagnostically relevant assertion that no silicone is present in the folds is conclusive based on the separated images.

Conclusion: The implemented multi-echo TSE sequence acquired the necessary 5 echoes within a very reasonable acquisition time of 4.5min. The acquired phase correction data were sufficient to correct the phase errors introduced by the bipolar readout gradients. The region-growing stabilized VARPRO algorithm cleanly separated the three spectral components water, fat and silicone and proved robust against in-vivo typical B0 inhomogeneities. However, the residual fat signal in the implant's saline solution compartment needs further investigation. The potential of the proposed sequence and separation to provide both T2-weighted images as well as a silicone-only image is apparent, especially since the provided SNR is sufficient for parallel imaging acceleration and an increase in resolution.

References: [1] Jochimsen TH, *et al.* JMR 2004;170:67-78. [2] Hernando, D., *et al.* MRM 2008;59:571-580. [3] Ma J. MRM 2004;52:415ff

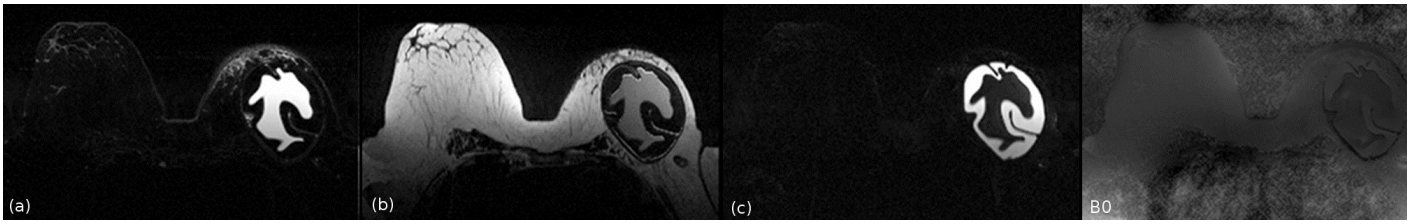

Fig 2: Results of the region-growing VARPRO separation for an in-vivo dataset of a 64 year old patient with an unilateral silicone implant. (a) shows the water image, (b) fat image and (c) silicone image. On the right is the calculated B0 inhomogeneity map. The silicone implant consists of two compartments. An outer shell with silicone and an inner volume filled with a saline solution.