BREAST IMPLANT MRI WITH AN EXTENDED 4-POINT IDEAL METHOD

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Target audience: Physicists, clinicians and radiographers with an interest in breast MRI.

Purpose: MRI is widely used for imaging of patients with silicone breast implants, in particular to check for implant integrity, a question that has become very topical of late with concerns over Poly Implant Prothèse (PIP) implants [1]. To check for extracapsular silicone, imaging protocols often incorporate a silicone only sequence, typically suppressing fat with inversion recovery (IR) and water with frequency selective saturation [2], and combinations of IR and Dixon methods have also been proposed [3,4]. These, however, are susceptible to main field inhomogeneities (spectral methods) and/or reduced SNR (IR). Furthermore the suppressed components are lost and so further acquisitions may be required, e.g. fat + silicone-suppressed imaging when there are additional questions regarding possible malignancy. A 4-point version of the IDEAL method to provide separate images of water, fat and silicone was previously suggested and tested in phantoms [5], however to the best of our knowledge it has not been implemented *in vivo*. We present an extension of the 4-point IDEAL method, introducing an optimised initial echo time and a region growing algorithm [6] to provide a better initial B0 estimation, and demonstrate the first clinical results from a breast implant patient.

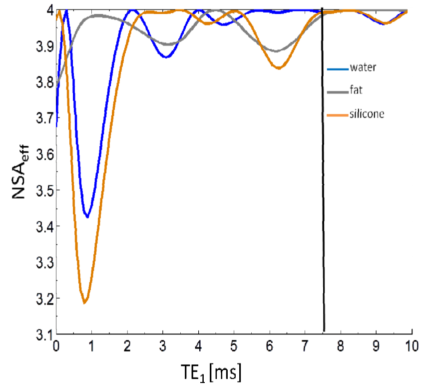

Fig 1. Identifying best initial echo times (TE_1). Theoretical calculation of maximum number of effective signal averages vs. initial echo times, reflecting the amount of information in acquired images and thus likelihood of reconstruction converging to the correct solution. The lowest TE_1 at which NSA_{eff} for all species is at the maximum value (4) is at 7.55 ms.

Methods: To find the optimal initial echo time (TE_1) a previous analysis [7] was extended to a 4-point model calculating the maximum number of effective signal averages (NSA_{eff}) for water, fat (-210 Hz with respect to water at field strength of 1.5T) and silicone (-310 Hz) from the diagonals of Fisher Information Matrix for a signal model for different values of TE_1 including B0 inhomogeneity and with a previously defined optimal TE spacing of 2.4 ms [5]. These represent how much unique information about each species is contained within the image. Thus maximising NSA_{eff} for each species ensures the highest chance of correctly separating the species (Fig 1). Based on these findings, 2D gradient echo images with TEs 7.55, 9.95, 12.35, 14.75 ms were acquired on a 1.5T Aera system (Siemens, Erlangen, Germany) from a 20 cm bowl containing oil, water doped with 0.1% of Gd contrast agent, and a silicone breast implant. A 4-point IDEAL reconstruction [5] with a region growing algorithm [6] for an initial B0 estimate was implemented in Matlab (MathWorks, Natwick, MA, USA). Following confirmation of the technique *in vitro*, similar images were acquired from a patient with a breast implant in accordance with local ethics approval and informed consent. *In vivo* images were divided in two for the purposes of reconstruction, separating the left and right breast. Routine silicone-only sequences (fat suppression via STIR + frequency selective water suppression) were acquired for comparison.

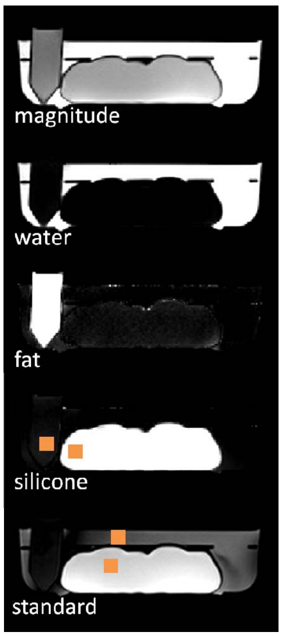

*Fig.2. Separated phantom images. Standard clinical protocol (**bottom**) silicone-only image (fat and water suppressed by STIR and spectral methods respectively) shows variation in degree of water suppression. Comparing signal strength in regions of interest (orange) shows superiority of 4-point IDEAL.*

Results: Theoretical analysis suggests using 7.55 ms as an initial echo time to maximise the likelihood of the reconstruction converging at the correct solution (Fig 1), as it is the lowest value for TE_1 where the NSA_{eff} of all species reach the maximum value of 4. Reconstructed phantom images showed good separation of all the species (Fig. 2). The ratio of silicone to residual neighbouring signal was 8.5 for 4-point IDEAL, compared with only 2.3 for the routine silicone-only sequence. *In vivo* the 4-point IDEAL method showed good separation in each of the reconstructed images (Fig. 3). The ratio of silicone signal to neighbouring tissue was 6.6 for both the 4-point IDEAL and standard protocol. Regions of interest were chosen to reflect the 'worst case scenario', i.e. where residual signal was the strongest. The 4-point IDEAL method showed noticeably improved suppression of non-silicone species in the contralateral breast compared to the routine silicone-only image.

Discussion: The proposed method offers images of quality comparable to that of a standard clinical protocol around the implant. In the routine silicone-only sequence poor suppression of non-silicone signal in the phantom and in the contralateral breast suggests 4-point IDEAL may be more suitable for imaging of larger volumes and bilateral implants. In addition to the silicone image, 4-point IDEAL produces water and fat images, which can offer more diagnostic information, e.g. if there is an oncology-based query, and thus reduce overall examination time by eliminating the need for further acquisitions . Its disadvantage is that like all region-growing methods it is sensitive to the selection of reconstruction starting point. Further work looking at varying delta TEs may provide additional optimisation of this technique.

Conclusion: 4-point IDEAL combined with region growing offers a robust and time efficient assessment of implant integrity in breast MRI, and provides water and fat images for extra diagnostic information.

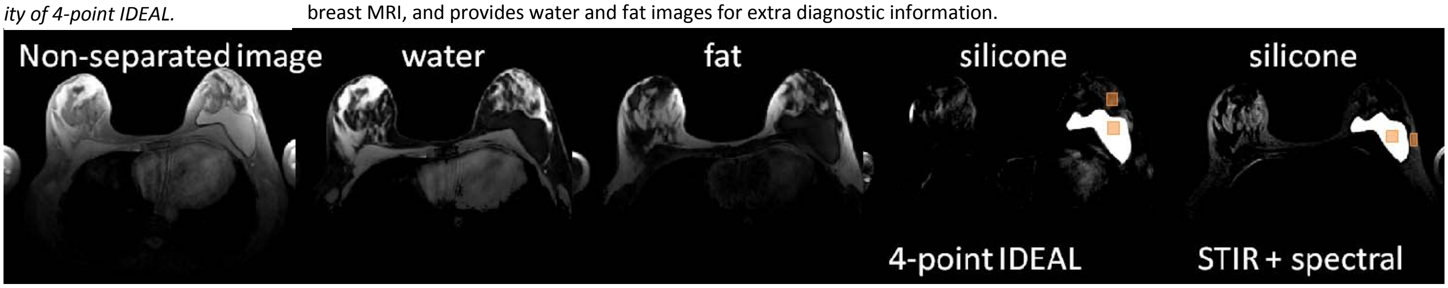

Fig.3. Separated in vivo *images and comparison with standard clinical protocol combining STIR and spectral suppression of signals. Both methods produce similar results around the implant, where ratio of silicone to residual signal (orange areas) is 6.6.The ROIs were chosen to compare areas with strongest residual signal with silicone in their neighbourhood. The standard method fails in the other breast, indicating that it may cause issues over a large volume. This is supported further by the failure of the method to suppress signal in the phantom. 4-point IDEAL produces additional water and fat images, potentially increasing diagnostic value.*

References: [1] Heneghan, *BMJ* 2012;344:e306; [2] Kreymerman, Ann Plast Surg 2009; 62:355-357; [3] Mukundan et al, JMRI 1993; 3:713-717; [4] Ma et al., JMRI 2004;19:298–302; [5] Reeder et al., MRM 2004; 51:35-4); [6] Yu et al, MRM 2005; 54:1032-1039; [7] Pineda et al., MRM 2005; 54:625-635