Fat suppression techniques for high resolution breast DCE MRI at 7 tesla: a qualitative and quantitative comparison

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Introduction: High resolution Dynamic Contrast Enhanced (DCE) MRI is used for the diagnosis of breast cancer. Care must be taken to avoid subtraction artefacts coming from the short T_1 of lipid tissue. Therefore, robust lipid suppression is crucial, particular at ultra-high spatial resolution. With the recent availability of bilateral breast coils for 7 tesla MR systems[1,2,3], the question rises which fat suppression technique one should use to benefit from the high resolution DCE MRI available at 7 tesla without sacrificing contrast-to-noise. To avoid prolongation of TR (like in SPAIR), efficient fat suppression can be obtained with chemical shift selective excitation (ProSet) or dual echo (Dixon) techniques. Yet, ProSet is sensitive to magnetic field non uniformities, while Dixon can be hindered by T2* effects in multi-echo (ME) mode or by movements in multi acquisition (MA) mode. In this study we compared the efficiency of thee fat suppression techniques that can be applied for high resolution DCE MRI.

Methods: Ten healthy female volunteers where scanned on a Philips Achieva 7 tesla MR System (Cleveland, OH, USA), with bilateral breast transmit/receive coil (MR Coils B.V., Drunen, the Netherlands). 3rd order image based shimming was performed prior to the acquisitions. Imaging parameters of the different fat suppression sequences are shown in Table 1. Qualitatively assessment was performed by a radiologist with 8 years of experience in breast MR. The overall image quality and visibility of anatomical details where scored on a scale from 1 (no diagnostic value) to 5 (excellent). The presence of artefacts, the homogeneity of fat suppression and the presence of water-fat shift were scored on a scale from 1 (not present) to 3 (present and would influence the diagnosis). Quantitative analyses was based on comparing the contrast-to-noise ratios (CNR) of different regions of interest (ROI). A pairwise Kruskal-Wallis 1-way Anova analyses was performed on all measures.

	Field of View (mm^3)	Resolution (mm^3)	TE / TR (ms)	Flip angle	Acquisition time (mm:ss)
ProSet	339x119x147	0.8x0.8x0.8	3.2 / 6.7	8°	03:19
MA Dixon	339x119x147	0.8x0.8x0.8	2.96-3.46 / 6.2	8°	06:07
ME Dixon	339x119x147	0.8x0.8x0.8	2.5-3.9 / 6.0	8°	03:00

Table 1 *Selection of scan parameters of the acquired scans.*

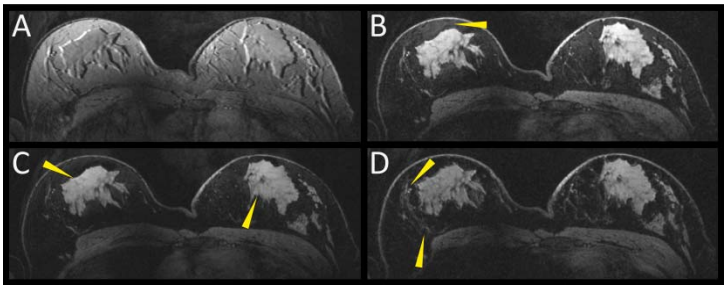

Figure 1 *Examples of a non-fat suppressed scan (A) and ProSet(B), MA Dixon (C) and ME Dixon (D) fat suppression. ProSet sometimes has inhomogeneous fat suppression, caused by shim imperfections and the high B_1^+ and B_1^- of the coil at the anterior side. However, enough contrast between glandular and fatty tissue is available. Details within glandular tissue are less visible using MA Dixon. This may be caused by B_0 variations between the two acquisitions. Small anatomical details tend to blur out when using ME Dixon. The 2nd echo of the ME Dixon is T_2^*-weighted, making it difficult to extract the required information. Markers in the image indicate examples of the described artefacts.*

Results: An example of the fat suppressed scans is shown in figure 1, demonstrating high T_1 weighting (strong non-suppressed lipid signal in 1A) and effective lipid suppression (1B,C,D). Inhomogeneous fat suppression can be observed in the ProSet acquisition (1B). Loss of small details within the glandular tissue can be seen in the MA Dixon acquisition (1C). Anatomical details are blurred out in the ME Dixon acquisition (1D). The qualitative scores are displayed with Box-and-Whisker plots with 95% confidence intervals in figure 2. A significant difference between ProSet and ME Dixon was found for the overall image quality and the presence of artefacts. The CNRs between parenchym and fat of different ROIs are shown in table 2. No significant difference was found between the different methods.

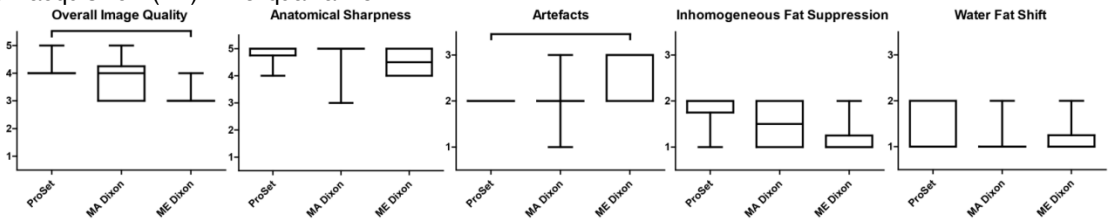

Figure 2 *Box-and-Whisker plots of the qualitative results. The overall image quality was scored on a scale from 1 (no diagnostic value) to 5 (excellent). The presence of Artefacts, Inhomogeneous fat suppression and the presence of water fat shift were scored from 1 (not present) to 3 (Present and influencing the diagnosis). Significant differences, visualized by a cap over the plots, were found between ProSet and ME Dixon when looking at the overall image quality and the presence of artefacts.*

	left medial parenchym-fat	left lateral parenchym-fat	right medial parenchym-fat	right lateral parenchym-fat
ProSet	43 ± 22	30 ± 16	28 ± 9	22 ± 9
MA Dixon	36 ± 24	27 ± 12	34 ± 19	23 ± 10
ME Dixon	22 ± 9	20 ± 8	16 ± 6	13 ± 4

Table 2 *Contrast to noise ratios of different regions of interest. No significant differences were found between the fat suppressed methods.*

Discussion: The inhomogeneous fat suppression of the ProSet scan can be caused by a shimming offset and the transmit and receive profile of the coil at the anterior side of the body. However, there was enough contrast-to-noise to differentiate glandular from fatty tissue. The loss of detail in the MA Dixon scan are likely to be caused by shot-to-shot variability between the two Dixon acquisition. This variation can be caused by, e.g. B_0 fluctuations over to the respiration cycle, or due to partial volume effects within the voxel. The loss of detail in the ME Dixon scan is caused by the T_2^*-weighted 2nd echo. Little signal is left in this 2nd echo to accurate determine the complex signal required for the post processing. This is also expressed in the relatively low CNRs in table 2, a less good image quality and the presence of artefacts that would influence the diagnosis in some cases. ProSet and MA Dixon perform similar in both the qualitative as the quantitative scoring. It should be taken into account that, with the same resolution, MA Dixon takes twice the amount of scan time compared to ProSet. This means that ProSet can achieve a higher temporal resolution or spatial resolution in the same scan time. Therefore it is expected that ProSet will reveal the most details between tumorous and fibroglandular tissue after the injection of a gadolinium compound.

Conclusion: Within the context of high resolution DCE MRI of the breast, the ProSet fat suppression performs better than the ME Dixon and MA Dixon methods per unit of time.

[1] Gruber et al. Investigative Radiology, 2014, Vol.49-5 p354-362
[2] Brown et al. Journal of Magnetic Resonance Imaging, 2014 Vol.39-3 p540-549
[3] van der Velden et al. ISMRM 2014 #1307