Clinical assessment of complex valued combinations of ip- and op-data in MR mammography

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Introduction

It has been shown that the combined use of complex valued in-phase (ip) and opposed-phase (op) images can improve the signal to noise ratio (SNR) of dynamic MR mammography (MRM)[1] compared to conventional ip-subtraction (SIP_{CN}). While improved SNR is certainly helpful, this study is comparing the overall image quality and especially the lesion sharpness of four different contrasts to evaluate their value for clinical use. Here the lesion delineation is of particular interest since one of the most critical morphological criteria is the sharpness of the lesion boundary.

Material and Methods

For 19 patients ip (TE=4.76ms) and op (TE=2.41ms) data were acquired on a 1.5T scanner with a 3D dual echo gradient echo sequence during routine dynamic MRM examinations. The scan parameters were a matrix of 384x384, slice thickness 3mm, TR=7.5ms, BW 725 Hz/px, α=18° in transversal orientation. The total imaging time was 60s, one native scan followed immediately by the injection of 0.1mmol/kg Gd-DTPA and 7 more scans starting 30s after the native scans. The resulting magnitude and phase images were transferred to a dicom node and post-processed on a multicore computer using a parallelized C++ software. All subtraction contrasts were rescaled after calculation to span the full 12 bit pixel depth of dicom images and transferred back to the scanner for timely evaluation (calculation time ~30s). For the clinical evaluation four particularly promising contrasts [1] were selected (Eq. (1)-(4)) where S_C is the signal post contrast agent (CA) and S_N the native signal. Only repetition 2 after CA injection was used for image quality assessment because lesion border delineation is best in early phase enhancement. Two independent observers, one experienced (>1000 examinations) in reading MRM and the other one a novice to MRM, rated the four contrasts on an ordinal scale of 0-3 (0 poor, 1 acceptable, 2 good, 3 excellent) for overall image quality and for lesion border delineation.

$$\mathrm{SIP_{CN}} = \left|S_C^{\mathrm{ip}}(t)\right| - \left|S_N^{\mathrm{ip}}(t)\right| \quad (1)$$

$$\mathrm{cAIPOP} = \left|S_C^{\mathrm{ip}}(t) + S_C^{\mathrm{op}}(t)\right| - \left|S_N^{\mathrm{ip}}(t) + S_N^{\mathrm{op}}(t)\right| \quad (2)$$

$$\mathrm{MIP_{mag}} = \mathrm{MIP}\Big(\left|S_C^{\mathrm{ip}}(t)\right| - \left|S_C^{\mathrm{op}}(t)\right|,\ \left|S_C^{\mathrm{ip}}(t)\right| - \left|S_N^{\mathrm{op}}(t)\right|\Big) - 0.75 \cdot \Big(\left|S_N^{\mathrm{ip}}(t)\right| - \left|S_N^{\mathrm{op}}(t)\right|\Big) \quad (3)$$

$$\mathrm{MIP_{cmplx}} = \mathrm{MIP}(\mathrm{cAIPOP}, \mathrm{MIP_{mag}}) - 0.75 \cdot \Big(\left|S_N^{\mathrm{ip}}(t)\right| - \left|S_N^{\mathrm{op}}(t)\right|\Big) \quad (4)$$

Results

The results of the contrast evaluation for each observer (mean and standard deviation, n= 19 patients) are shown in the table. MIP_{cmplx} was found to be superior to all other contrasts regarding image quality as well as border delineation ($p \leq 0.005$). Image quality of SIP_{CN} was rated inferior to all other contrasts by observer 1 ($p \leq 0.002$) whereas observer 2 found no significant differences between SIP_{CN} and MIP_{mag}. For border delineation, cAIPOP and MIP_{cmplx} were rated better compared to SIP_{CN} and MIP_{mag} by both observers.

Contrast	Observer 1 (MRM novice)		Observer 2 (MRM expert)	
	Image quality	Border delineation	Image quality	Border delineation
SIP_{CN}	0,95±0,5	0,79±0,6	1,42±0,6	1,21±0.5
cAIPOP	1,68±0,7	1,79±0.7	1,95±0,8	2,16±0.6
MIP_{mag}	1,74±0,9	1,21±1,1	1,21±0,8	1,16±1,1
MIP_{cmplx}	2,47±0,5	2,58±0.6	2,47±0,6	2,63±0.6

Conclusion

The complex valued processing for cAIPOP increases the dynamic range and SNR of the resulting images compared to the regular ip-subtraction (SIP_{CN}). This often results in a better delineation of lesion boundaries, but very weak partially volumed extensions might be overwhelmed by the high signal in the lesion center. Furthermore, since cAIPOP consists of two terms which represent an image with the water content only (fat signal cancels out), the motion artefacts at fat-parenchyma boundaries are much less pronounced as in SIP_{CN}. When voxels contain only a small fraction of an enhancing lesion (partial volume) the sensitivity of the contrasts can be greatly improved by a magnitude combination of ip and op (MIP_{mag}) [2]. This contrast can effectively be combined with cAIPOP into the new MIP_{cmplx} contrast encompassing both advantages – partial volume enhancement and contrast boost for the lesion boundaries. Both observers rated MIP_{cmplx} as being superior to regular in-phase subtraction (SIP_{CN}) with regard to image quality and lesion border delineation. Although based on a rather small number of patients, these preliminary results showing improved image quality and border delineation promise a better lesion classification in MRM. Further study will be conducted on more patients with a variety of enhancing lesions.

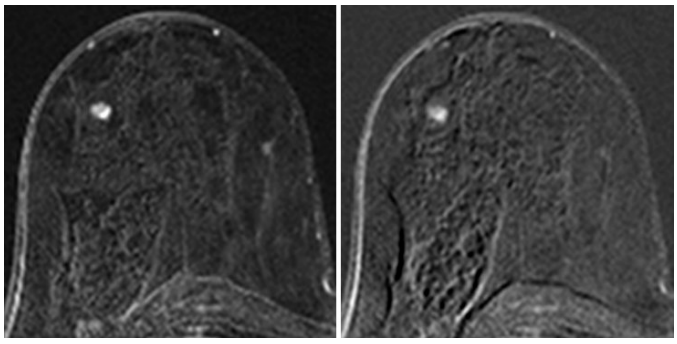

Fig 1: left MIP_{cmplx}, right SIP_{CN} The enhancing lesion represents a histologically confirmed fibroadenoma. Typical lobulated shape and sharp border is better depicted in MIP_{cmplx}.

[1] K.-H. Herrmann et.al. ISMRM 2008 (#2756)

[2] J.R. Reichenbach et al. J Magn Reson Imaging 2005 21(5): 565-575