Combining complex in-phase and opposed-phase data to improve contrast in dynamic MR Mammography

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Introduction

Simultaneous acquisition of in-phase (ip) and opposed-phase (op) data of a dynamic MR time series allows to create a multitude of new image combinations, which may generate new beneficial or even superior contrasts [1,2] compared to a standard ip image magnitude subtraction. The potential of two particularly promising new contrasts were investigated by analyzing in vivo MRM patient data.

Methods

Denoting the native signal as S_N and the contrast enhanced (CE) signal as S_C the following contrasts were calculated:

$$\left|S_C^{\mathrm{ip}}(t)\right| - \left|S_N^{\mathrm{ip}}(t)\right| \tag{1}$$

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

$$\mathrm{MIP}\Big(\left|S_C^{\mathrm{ip}}(t)\right| - \left|S_C^{\mathrm{op}}(t)\right|, \quad \left|S_C^{\mathrm{ip}}(t)\right| - \left|S_N^{\mathrm{op}}(t)\right| \Big) \tag{3}$$

$$\left|S_N^{\mathrm{ip}}(t)\right| - \left|S_N^{\mathrm{op}}(t)\right| \tag{4}$$

where the maximum intensity projection (MIP) operator returns the higher signal intensity of the two given contrasts.

In this pilot study dynamic MR mammography data were acquired in five patients with invasive carcinoma with a dual echo gradient echo sequence (TE1/TE2/TR/α = 2.38/4.76/8ms/12°, matrix 384x384) at 1.5 T. One native scan (TA=60s) was followed by 7 post contrast scans. Magnitude and phase images were saved to reconstruct the complex data. As an example, Fig 1 (a), (b) and (c) show the result of eqn. (2), (3) and (1), respectively. Applying the MIP operator to Fig. 1a and Fig. 1b and subsequently subtracting from this MIPed image the image calculated using eq. (4) and multiplied by a factor of 0.75 yielded the final image shown in Fig 1d.

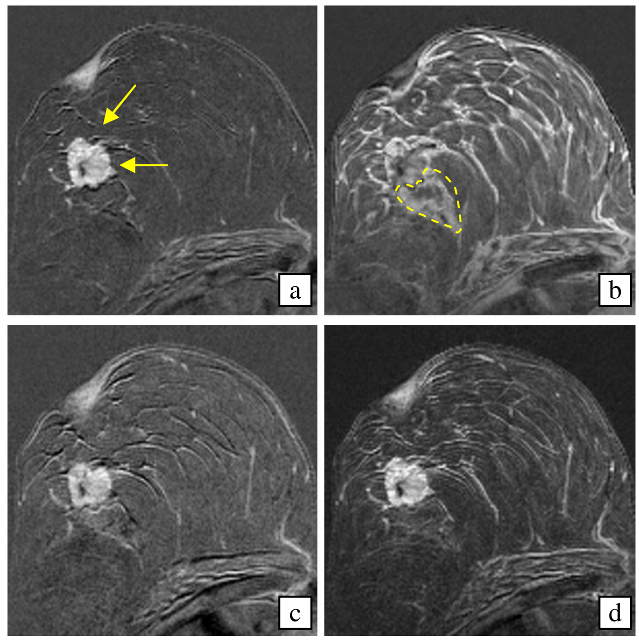

Figure 1: Patient with invasive ductal carcinoma. **(a)** image calculated from eq.(2). **(b)** image from eq. (3) Note the invasive infiltration of Cooper ligaments. **(c)** conventional ip-subtraction eq.(l). **(d)** MIP of eq. (2) and (3) minus eq. (4) (see text).

Results

In all patients a clear improvement of the lesion contrast was observed for images calculated from eq. (2) compared to the standard ip magnitude subtraction. Although complex image combination could in principle cause signal cancellation, total signal cancellation was not observed in the acquired patient data sets. For instance, comparing the four images in Fig. l one can clearly see the improved lesion to parenchyma contrast in (a) compared to (c). A ROI based evaluation yielded a CNR of 30 for (a) and 19 for (c), which agrees quite well with the theoretically predicted factor of 2 [2]. Note the highly improved delineation of lesion border and rim structures, such as the septal infiltration (arrows in 1a), which can be also seen in (d) but to a lesser extent in (c). The slight, but distinct non-mass enhancement (see ROI in b), which is most likely a reactive enhancement in proteolytic disintegrated tissue caused by tumor metabolism, is also visible in Fig. 1d, but barely seen in Fig 1c.

Discussion

The (complex) combination of ip and op data in dynamic improves lesion contrast (eq. 2) and enhances anatomical structures (eq. 3) like the Cooper ligaments. Using the contrasts shown in Fig. la, b and d in addition to the conventional subtraction (Fig.lc) provides additional information which may improve diagnosis and specificity of breast lesions. Further studies with a much larger patient base and different pathologies are certainly needed. Further intelligent contrast combinations may also help to reduce the amount of images which have to be analyzed.

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

[2] Herrmann, K.-H., et al. In Proc. Int. Soc. Magn. Reson. Med. 2006 (#1537)